NASA-TM-82278

Environmental Impact Statement

Space Shuttle Program

Final

April 1978

(NASA-TM-82278) ENVIRONMENTAL IMPACT STATEMENT FOR THE SPACE SHUTTLE PROGRAM Final Report (National Aeronautics and Space Administration) 296 p HC A13/MF A01 CSCL 13B G3/45

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National Aeronautics and Space Administration

Washington, D.C.
20546

SUMMARY

ENVIRONMENTAL IMPACT STATEMENT
FOR THE
SPACE SHUTTLE PROGRAM

(1977-1978 REVISION)

( ) Draft (X) Final Environmental Impact Statement

RESPONSIBLE FEDERAL AGENCY:

National Aeronautics and Space Administration
Washington, D.C. 20546

FOR ADDITIONAL INFORMATION, CONTACT:

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space Administration
Washington, D.C. 20546
(202) 755-3247

1. TYPE OF ACTION: (X) Administrative ( ) Legislative

2. BRIEF DESCRIPTION OF ACTION AND PURPOSE: The proposed action is the continued development and the follow-on operation of the Space Shuttle -- a piloted, recoverable, reusable space transportation system for providing rapid, easy, and economical access to space. The Space Shuttle will replace most of the present expendable launch vehicles and will greatly expand the Nation's capability to carry out beneficial space activities. The Space Shuttle is expected to make its first orbital test flight in 1979 and, as currently designed, to operate for at least a decade thereafter.

3. SUMMARY OF ENVIRONMENTAL EFFECTS: Test firings and launches will release air pollutants, causing a temporary localized small degradation in air quality near the test site or launchsite. Areas adjacent to the site will also be subjected to moderate sound levels of predominantly low frequencies for short durations. During the launch phase, hydrogen chloride will be introduced into the stratosphere, causing a small decrease in ozone. Temporary perturbations to the ionosphere will occur during orbital maneuvers and entry and will have no significant effect on communication or radio wave propagation. As the Orbiter descends, a low-magnitude sonic boom will be produced along the groundtrack with the maximum overpressures occurring near the landing site. The overpressures will be infrequent, will vary in location, and are of sufficiently low energy to be considered a momentary annoyance, if noticed at all.

4. MAJOR ALTERNATIVES CONSIDERED: The alternatives considered are discontinuation or postponement of the program (equivalent to continuation of expendable launch vehicles for each Space Shuttle mission), use of alternate propellants, and neutralization of the ground cloud.

5. COMMENTS REQUESTED FROM:

Advisory Council on Historic Preservation
Advisory Council on Intergovernmental Relations
Agency for International Development
Council on Environmental Quality
Department of Agriculture
Department of the Air Force
Department of the Army
Department of Commerce
Department of Defense
Department of Health, Education and Welfare
Department of Housing and Urban Development
Department of the Interior
Department of the Navy
Department of State
Department of Transportation
Department of the Treasury
Environmental Protection Agency
Energy Research and Development Administration
Federal Aviation Administration
Federal Communications Commission
Federal Maritime Commission
Federal Power Commission
General Services Administration
National Academy of Sciences
National Science Foundation
Office of Management and Budget
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New Hampshire Clearing House
New Jersey Clearing House
New Mexico Clearing House
New York Clearing House
North Carolina Clearing House
North Dakota Clearing House
Ohio Clearing House
Oklahoma Clearing House
Oregon Clearing House
Pennsylvania Clearing House
Rhode Island Clearing House
South Carolina Clearing House
South Dakota Clearing House
Tennessee Clearing House
Texas Clearing House
Utah Clearing House
Vermont Clearing House
Virginia Clearing House
Washington Clearing House
West Virginia Clearing House
Wisconsin Clearing House
Wyoming Clearing House

Air Pollution Control Association
American Association for the Advancement of Science
American Conservation Association, Inc.
American Farm Bureau Federation
American Forestry Association
American Geophysical Union
Bureau of National Affairs
Center of Law and Social Policy
Chamber of Commerce of the U.S.A.
Citizens' Advisory Commission on Environmental Quality
Citizens' Committee on Natural Resources
Concern, Inc.
Conservation Foundation
Consumer Environmental News Service
Council on Economic Priorities
Ecological Society of America
Environmental Action Foundation
Environmental Action, Inc.
Environmental Defense Fund
Environmental Policy Center
Federation of American Scientists

Ford Foundation
Friends of the Earth
International Ozone Institute
League of Conservation Voters
League of Women Voters of the U.S.
National Association of Conservation Districts
National Audubon Society
National Commission on Supplies and Shortages
National Geographic Society
National Parks and Conservation Association
National Trust for Historic Preservation
National Wildlife Federation
Natural Resources Defense Council, Inc.
Sierra Club
The Conservation Foundation
The Environmental Law Institute
The Izaak Walton League of America
The Rockefeller Foundation
The Wilderness Society
The Wildlife Society, Inc.

6. COMMENTS RECEIVED FROM:

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Department of Transportation
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Federal Power Commission
National Science Foundation

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Kansas Clearing House
Maryland Clearing House
Mississippi Clearing House
Missouri Clearing House
Nevada Clearing House
New Jersey Clearing House
New Mexico Clearing House
North Carolina Clearing House
North Dakota Clearing House
Oregon Clearing House
Texas Clearing House
Washington Clearing House
Wyoming Clearing House

Center of Law and Social Policy

7. ISSUANCE OF STATEMENT: The draft environmental impact statement was submitted to the Council on Environmental Quality, Executive Office of the President, and made available to the public on August 5, 1977. This final environmental impact statement is being submitted to the Environmental Protection Agency and forwarded for notice to the public on MAY 9 1978

OVERVIEW

POTENTIAL ENVIRONMENTAL EFFECTS

The potential environmental effects resulting from the Space Shuttle Program are discussed in the initial environmental impact statement published in July 1972. Since that time, the National Aeronautics and Space Administration, in cooperation with outside experts and other government agencies, has had an aggressive and comprehensive environmental effects program. A reassessment of the potential environmental impacts has recently been evaluated, and the results are summarized as follows:

- Troposphere: A ground cloud will be formed by the Space Shuttle rockets during launch. This cloud consists of the exhaust products from the solid rocket motors and liquid engines, the products of afterburning in the exhaust plume, the air that is mixed with the exhaust gases, and much of the heat energy that is generated.

The direction, movement, and diffusion of the ground cloud have been the subject of an intensive analytical study during the past several years. A mathematical model has been developed which uses the characteristics of the rocket exhaust products and launchsite meteorology to predict the rise, growth, and dispersal of the ground cloud. To validate the model, seven Titan launches were monitored at the Kennedy Space Center, Florida, using aircraft-, ground-, and sea-based instrumentation to measure cloud concentrations and fallout of hydrogen chloride, carbon dioxide, and aluminum oxide particles. These are the primary exhaust products of the solid rocket motors which are of concern. In all cases, there was reasonable agreement between measurements and the model predictions.

Theoretical predictions for 45 hypothetical Shuttle launch cases, solid motors, and liquid engines firing simultaneously, gave concentrations of hydrogen chloride below the recommended exposure limits. The largest peak concentration of hydrogen chloride calculated was 3.9 parts per million, and the highest average exposure level over a 10-minute period was 1.2 parts per million. The exposure limit for hydrogen chloride recommended by the National Academy of Sciences is 4 parts per million for 10 minutes with a peak of 8 parts per million.

The hydrogen chloride from the solid rocket motors can also produce acidic rain if the Space Shuttle is launched during certain local meteorological conditions. In 1967, Aerojet General Corporation tested a 260-inch solid rocket motor during local shower activity which resulted in damage to lime groves. Acidic rainfall was measured for the first time during the Titan/Viking-B launch in September 1975, and pH values ranging from 1 to 2 were measured close to the launch complex. The National Aeronautics and Space Administration is continuing a research program to model the occurrence of acidic rain as a result of interaction of the ground cloud and local shower activity. These results, coupled with the ground diffusion model, will predict the acidity of rainfall that might occur. The results of this program will provide a model to define in advance the go/no-go (launch constraints) criteria to minimize unacceptable environmental effects from acidic rainfall. The Shuttle

exhaust cloud might initiate rainfall if it encounters active precipitation cells or might suppress rainfall if it encounters a shallow, warm cloud. While such weather modification is difficult to assess, its occurrence is considered unlikely. Should such potential effects occur, they would be confined to an extremely small area and would last for a short time after a launch. If necessary, such effects can be precluded by launch criteria, as in the case of acidic rain.

- Sonic Boom: During ascent of the Space Shuttle, as the vehicle pitches over, acoustical energy is focused in a narrow dish-shaped region over the ocean across the flightpath. Using prediction techniques, the estimated ascent overpressure (without focusing effects) is 287 newtons per square meter (6 pounds per square foot) about 64 kilometers (40 miles) downrange. Focusing effects could occur during the pitchover maneuvers and increase the overpressure. As with present rocket launches, sea traffic can be restricted in those areas.

The Orbiter will also produce a sonic boom during entry. Because of the large range of entry trajectories, part of the boom may occur over land. Overpressures have been calculated for these conditions, and trajectories have been tailored to minimize the effect on the ground. Studies are continuing in this area, and current estimates indicate that maximum overpressures will be about 96 newtons per square meter (2 pounds per square foot) in a small area within about 48 kilometers (26 nautical miles) of the landing site. These overpressures are in the range of nuisance or annoyance according to the report issued by the Sonic Boom Panel of the International Civil Aviation Organization in October 1970. They will be infrequent so that the annoyance should be minor compared to the 10 or 15 sonic boom events per day cited in the report issued by the Panel.

- Stratosphere: The Space Shuttle exhaust releases water, hydrogen chloride, chlorine, and aluminum oxide particles into the stratosphere and produces some nitric oxide in the hot plume. The quantity of water released by the Space Shuttle is very small compared to natural sources, and its effect on the ozone density will be insignificant. Model calculations of the effects of aluminum oxide and nitrogen oxides have been made, and the results indicate that they are also negligible. Chlorine compounds do affect the ozone density.

The potential effect of Space Shuttle emissions on the stratosphere was evaluated using the projected Space Shuttle launch rate, peaking at a steady state of 60 flights per year. This launch rate was used in a one-dimensional model to predict hemispherically averaged chlorine concentrations as a function of altitude and time.

From calculations made by five different scientific groups in early 1977, the maximum steady-state reduction of ozone was estimated to be 0.2 percent, supported by an independent study of the National Academy of Sciences, which predicted 0.15 percent. Later in 1977, it was established that the $HO_2 + NO \rightarrow OH + NO_2$ reaction rate was much faster than previously supposed. This reaction is significant in stratospheric ozone chemistry, and a larger value for its rate leads to a larger ozone reduction effect. The addendum in the draft environmental impact statement indicates that the effect might

be as large as a factor of 2. New calculations, using the same models as before but with the new reaction rate, indicate that the Northern Hemisphere's average ozone reduction is about 0.25 percent, a slight increase from the previous value. This is considered insignificant and undetectable compared to the much larger natural variations in stratospheric ozone levels.

- Ionosphere: During Orbiter maneuvers above an altitude of 180 kilometers (the F-region), the exhaust products from the Orbital Maneuvering System will reduce the ion concentration. This effect is very localized and temporary. Effects on radio wave propagation will be insignificant.

During Orbiter entry, between a 70- and 90-kilometer altitude (the D-region), some of the heated atmosphere will be converted to nitric oxide, which ionizes in ultraviolet sunlight. The length of the trail may be one-fourth the circumference of the Earth, but the width will be quite narrow. The required time for the trail to disappear has been calculated to be less than 1 day and in the presence of wind shears, only hours. The effects of the ionized trail on radio wave propagation are expected to be insignificant. The long-term effects of this nitric oxide on the stratosphere have also been studied and have been determined to be negligible.

- Medical and Biological Effects: The Space Shuttle's impact on the tropospheric regions of the atmosphere will have no significant medical (human) or biological (plants and animals) effects, and efforts are continuing to confirm this prediction. A baseline or library of existing flora and fauna is being obtained to differentiate seasonal, climatic, and other changes (natural or manmade) occurring at the Kennedy Space Center launchsite.

In the stratosphere, the estimated depletion of ozone can be converted into an estimate of the increase in ultraviolet radiation from the Sun reaching the ground. It is generally assumed that an X percentage of ozone reduction results in a 2X percentage increase in ultraviolet radiation. Based on the limited available biological data, the impact of a 0.25-percent reduction in ozone will not be detectable without decades of observation. The natural ultraviolet irradiances are highly variable and exceed the Shuttle predicted ozone change by an order of magnitude. The responses and the repair of organisms to given doses and dose rates of ultraviolet radiation are also highly variable. These factors preclude the prediction of the effect of such a small increase in ultraviolet radiation on skin cancer.

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1. INTRODUCTION

1.1 Background

The objectives of the Space Shuttle Program are to develop a reusable space shuttle vehicle capable of providing ready, low-cost access to near-Earth space and to provide for the conduct of space operations through the 1980's. As can be expected for a program of this size and complexity, a broad range of environmental parameters is affected during the developmental and operational phases of the program. These parameters have received considerable attention, and appropriate environmental impact statements have been prepared in accordance with the National Environmental Policy Act of 1969 (NEPA) and applicable regulations of the Council on Environmental Quality (CEQ) and the National Aeronautics and Space Administration (NASA).

On March 1, 1971, the first environmental impact statement for the Space Shuttle Program was released for comment. This statement, issued early in the program's study phase, described a system that was fully reusable and fueled by hydrogen and oxygen. The draft gave primary attention to the two principal environmental effects associated with the system's concept: noise and sonic boom.

During the latter part of 1971, as Space Shuttle design studies continued, it became apparent that certain alternative configurations and systems offered considerable technical and economic advantages. Environmental studies of these configurations and systems were undertaken, and a draft of the fully revised environmental impact statement was released in April 1972. This statement evaluated the environmental effects of a system very similar to the one presently being developed -- a system in which the reusable Space Shuttle Orbiter would be placed in orbit by the combined propulsion of its own main engines and a pair of reusable Solid Rocket Boosters (SRB's). The environmental factors evaluated included the effects upon air quality caused by the exhaust products of the SRB's and the noise and sonic boom associated with launch of the system and reentry of the Orbiter.

A final environmental impact statement for the Space Shuttle Program was released in July 1972 (ref. 1-1). In accordance with CEQ guidelines, NASA identified this environmental impact statement as a broad program statement to assess the overall impact of a large-scale program. Subsequently, NASA prepared and released for comment separate environmental impact statements on major individual actions within the scope of the overall Space Shuttle Program. Specifically, these individual actions involve a particular geographic locale and describe environmental effects limited to that locale. The program statement, on the other hand, describes both effects not restricted to a particular location and also the general features of the more significant local effects.

To date, NASA has prepared and released seven site-specific environmental impact statements in connection with the Space Shuttle Program (refs. 1-2 to 1-8). The U.S. Air Force (USAF) has also prepared an environmental impact statement; its statement (ref. 1-9) is on Space Shuttle-related construction and operations planned for Vandenberg Air Force Base (VAFB), California.

1.2 Purpose of This Revision

The CEQ guidelines on the preparation of environmental impact statements and the corresponding NASA guidelines give special consideration to environmental impacts associated with research and development (R&D) programs. The CEQ guidelines provide, in pertinent part, that "Statements must be written late enough in the development process to contain meaningful information but early enough so that this information can practically serve as an input in the decision-making process." Since R&D programs are characterized by the development of new information and the occasional necessity for major changes, it is implicit that environmental impact statements prepared early in the R&D process may require subsequent changes. These changes may be either in the form of amendments to incorporate specific new information of limited scope or of a major revision to reflect overall changes in program scope or in environmental understanding.

Since the release of the 1972 final environmental statement (ref. 1-1), new information has become available on certain environmental effects; and a number of design changes have altered somewhat the estimates of certain other environmental effects. The new information has been the subject of continual assessment to determine environmental impact. The present environmental impact statement, therefore, presents the results of the assessments (refs. 1-10 and 1-11) and constitutes a complete revision of the 1972 statement.

1.3 Scope

This revision to the 1972 broad program statement for the Space Shuttle Program includes descriptions of the environmental effects of the program as a whole, including the general nature of significant localized effects and more detailed analysis of the effects not restricted to specific localities. Program alternatives studied in 1972 are summarized, with more specific attention given to those alternatives that bear on the environmental factors for which new information is now available.

The purposes of the Space Shuttle missions will be to place in orbit various payloads and to conduct space research activities. At the present time, however, the listed environmental impact statements, both program and local site-specific, describe only those impacts associated with the Space Shuttle as a space transportation system (STS). Any environmental effects associated with payloads to be transported to space by the Space Shuttle will be covered in separate environmental impact statements, if warranted.

2. SPACE SHUTTLE PROGRAM

2.1 Background and Purpose

Since the space program began in the late 1950's, U.S. space missions have been performed using a family of expendable launch vehicles. The Saturn vehicles provided the launch capability for the manned lunar exploration program (Apollo), the manned space station missions (Skylab), and the joint U.S.-U.S.S.R. Apollo-Soyuz Test Project. The smaller Titan, Atlas, Delta, and Scout launch vehicles are currently used to launch a variety of automated spacecraft[1] (e.g., communications satellites, weather satellites, Earth-orbiting scientific satellites, and interplanetary exploratory spacecraft). These expendable launch vehicles have served the nation's space program well; however, their use is limited because of the cost incurred in constructing a new vehicle for each mission. In the late 1960's and early 1970's, the need was identified for replacing (by the early 1980's) the current expendable launch vehicles with low-cost reusable vehicles. The Space Shuttle has been designed to fill that need.

The Space Shuttle will make routine space operations possible. Space Shuttle flights will replace nearly all expendable launch vehicle missions, both civilian and military. Payloads carried to and from Earth orbit will include crew-operated, personnel-tended, or fully automated scientific or applications satellites. Payloads will be used for applications in Earth resources, environmental monitoring, communications, meteorology, and geodesy. The Space Shuttle will provide space transportation for operational and developmental payloads for NASA, the U.S. Department of Defense (DOD), the National Oceanic and Atmospheric Administration (NOAA), and other U.S. government users. It will also accommodate the space transportation needs of future commercial and international organizations on a cost-reimbursable basis.

2.2 Space Shuttle Vehicle

The Space Shuttle (fig. 2-1) consists of a piloted reusable orbiting vehicle (the Orbiter) mounted on an expendable External Tank containing hydrogen/oxygen propellants and two recoverable and reusable SRB's. The Orbiter will have three main hydrogen/oxygen liquid rocket engines and a cargo bay 18 m (60 ft) long by 5 m (15 ft) in diameter. Reference 2-1 provides considerable detail about the Space Shuttle.

The profile of a typical Space Shuttle mission is shown in figure 2-2. At launch, both the SRB's and the Orbiter's liquid rocket engines will burn simultaneously. When the Space Shuttle vehicle attains an altitude of approximately 43 km (27 miles), the SRB's will be separated and subsequently recovered from the ocean. The External Tank is jettisoned before the Orbiter goes into orbit. The Orbital Maneuvering System (OMS) is then used

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[1]Atlas and Titan vehicles were also used for the early Mercury and Gemini manned flight programs.

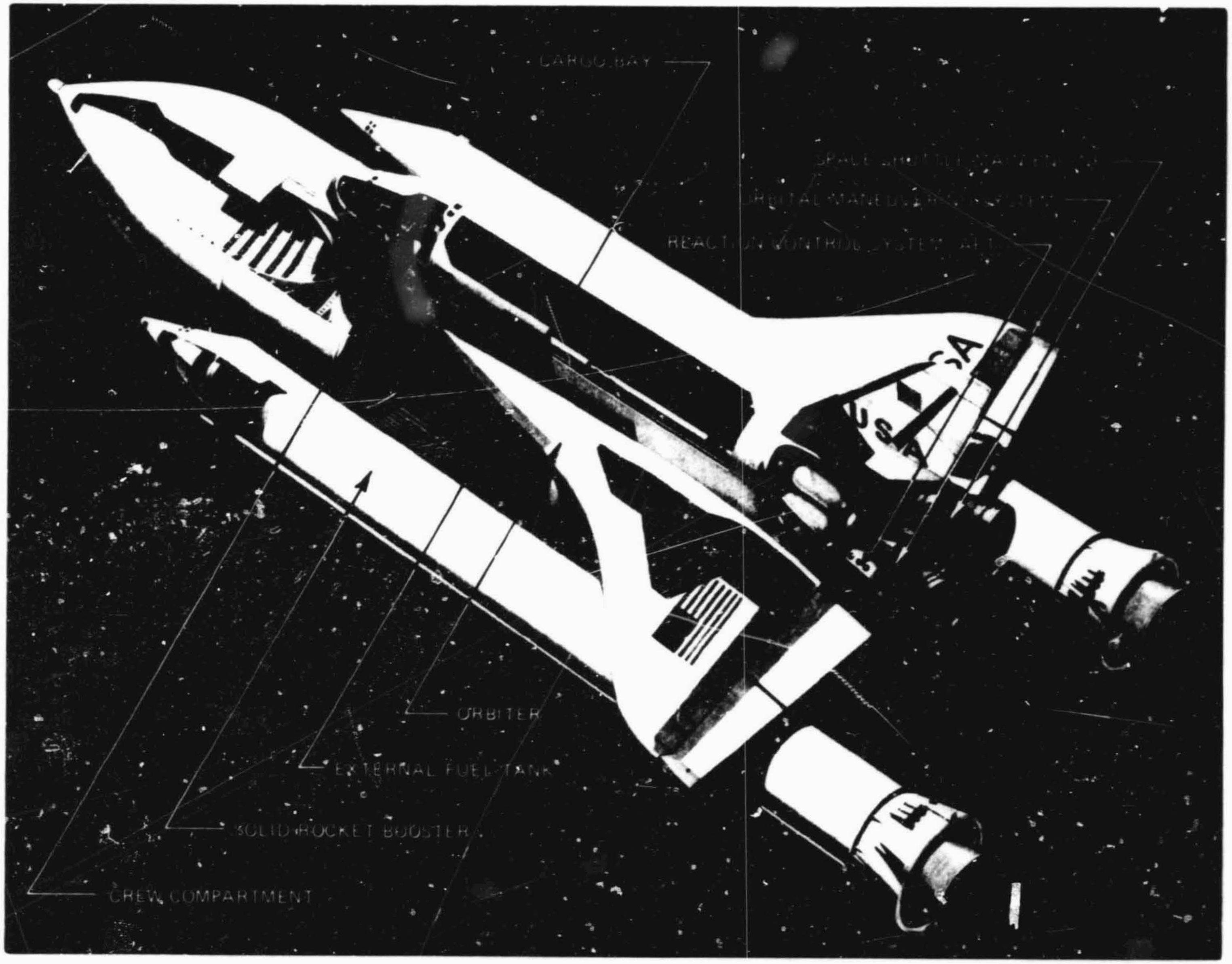
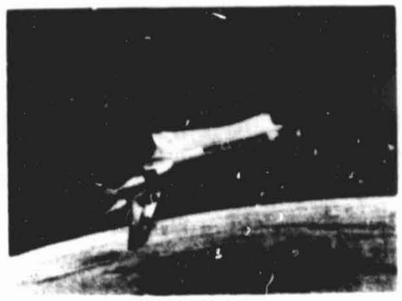


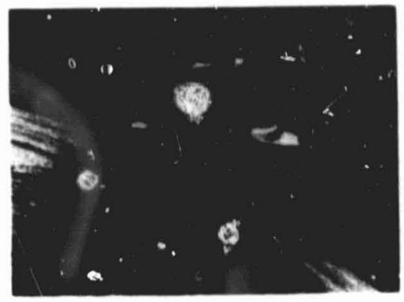
Figure 2-1.-- Space Shuttle vehicle.

SEPARATION OF EXTERNAL TANK



ORBIT INSERTION AND CIRCULARIZATION

ALTITUDE:
215 km (115 N. MI. - TYPICAL)
VELOCITY:
28 300 km/HR (17 600 MPH)

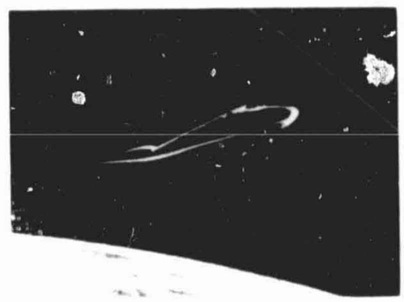


ORBITAL OPERATIONS

ALTITUDE:
185 TO 1100 km
(100 TO 600 N. MI.)
DURATION:
UP TO 30 DAYS

SEPARATION OF SOLID ROCKET BOOSTERS

HEIGHT:
43 km (27 MI.)
VELOCITY:
5170 km/HR (3213 MPH)



ATMOSPHERIC ENTRY

ALTITUDE:
140 km (76 N. MI)
VELOCITY:
28 100 km/HR (17 500 MPH)

SHUTTLE CHARACTERISTICS

(VALUES ARE APPROXIMATE)

LENGTH
- SYSTEM: 56 m (184 FT)
- ORBITER: 37 m (122 FT)

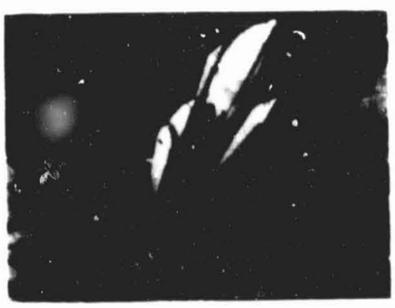
HEIGHT
- SYSTEM: 23 m (76 FT)
- ORBITER: 17 m (57 FT)

WINGSPAN
- ORBITER: 24 m (78 FT)

MASS
- GROSS LIFT-OFF:
  2 000 000 kg (4 400 000 LB)
- ORBITER LANDING:
  85 000 kg (187 000 LB)

THRUST
- SOLID ROCKET BOOSTERS (2):
  11 800 000 N (2 650 000 LB)
  OF THRUST EACH
- ORBITER MAIN ENGINES (3):
  2 100 000 N (470 000 LB)
  OF THRUST EACH

CARGO BAY
- DIMENSIONS:
  18 m (60 FT) LONG, 5 m (15 FT)
  IN DIAMETER
- ACCOMMODATIONS:
  UNMANNED SPACECRAFT TO
  FULLY EQUIPPED SCIENTIFIC
  LABORATORIES



SHUTTLE LAUNCH

LANDING

CROSSRANGE:
±2000 km (±1085 N. MI.)
VELOCITY:
346 km/HR (215 MPH)
(FROM ENTRY PATH)

Figure 2-2.-- Space Shuttle mission and characteristics.

to propel the Orbiter into the desired orbit. The Orbiter with its crew and payload will remain in orbit to carry out its mission, normally from 1 to 7 days but, when required, as long as 30 days. When the mission is completed, the Orbiter is deorbited and piloted back to Earth for an unpowered landing on a runway. The Orbiter and SRB's will subsequently be refurbished and reflown on other space missions.

2.2.1 Orbiter

The Orbiter (fig. 2-3) contains the crew and payload for the Space Shuttle system. The crew compartment can accommodate 7 crewmembers and passengers for some missions but will hold as many as 10 persons in emergency operations. It can deliver to orbit payloads of 29 500 kg (65 000 lb) with lengths of 18 m (60 ft) and diameters of 5 m (15 ft). The Orbiter is comparable in size and mass weight to modern transport aircraft; it has a dry mass of approximately 68 000 kg (150 000 lb), a length of 37 m (122 ft), and a wingspan of 24 m (78 ft).

The three main propulsion rocket engines used during launch are contained in the aft fuselage. The rocket engine propellants (liquid hydrogen and liquid oxygen) are contained in the External Tank, which is jettisoned before initial orbit insertion. The engines for the OMS are housed in two external pods on the aft fuselage. The OMS provides thrust for orbit insertion, orbit change, rendezvous, and return to Earth. The Reaction Control System (RCS) is located in the two OMS pods and in a module in the nose section of the forward fuselage. The RCS provides attitude control in space and precision velocity changes for the final phases of rendezvous and docking or orbit modification during reentry and descent. Both the OMS and RCS employ monomethylhydrazine (MMH) as fuel and nitrogen tetroxide as oxidizer. The various Orbiter aerodynamic control surfaces provide attitude control in the lower atmosphere. The Orbiter is designed to land at a speed of 95 m/sec (210 mph), similar to current high-performance aircraft.

The Orbiter structure is constructed primarily of aluminum protected by reusable surface insulation (RSI). The Thermal Protection System (TPS) is installed on the outer surface to protect the vehicle from the high temperatures generated during launch and reentry into the atmosphere from orbit. The TPS is composed of two types of RSI tiles, a high-temperature structure coupled with internal insulation, thermal windowpanes, coated Nomex felt, and thermal seals to protect against aerodynamic heating.

2.2.2 Solid Rocket Booster

Both SRB's burn for approximately 2 min with the main propulsion system of the Orbiter to provide initial ascent thrust during the Space Shuttle launch phase. Each SRB consists of several subsystems: the Solid Rocket Motor (SRM), various structures, separation motors, separation and recovery avionics, thrust vector control, and recovery systems. A cutaway view of the Space Shuttle SRB is shown in figure 2-4. The dimensions and the approximate weights and thrust of each SRB are cited in the figure.

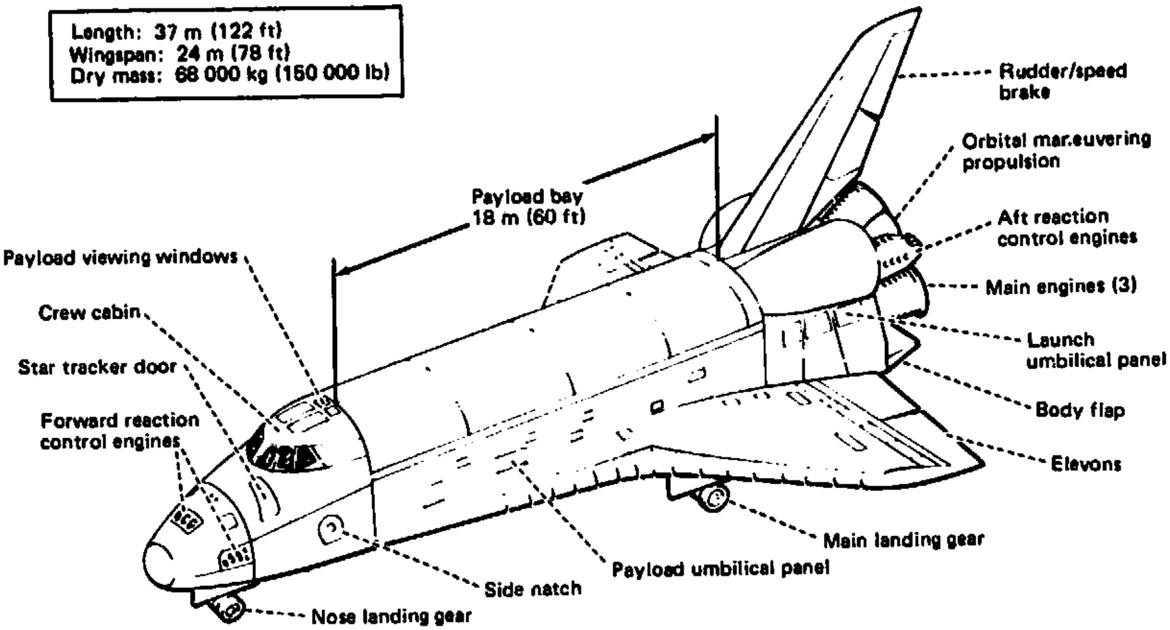


Figure 2-3.-- Space Shuttle Orbiter.

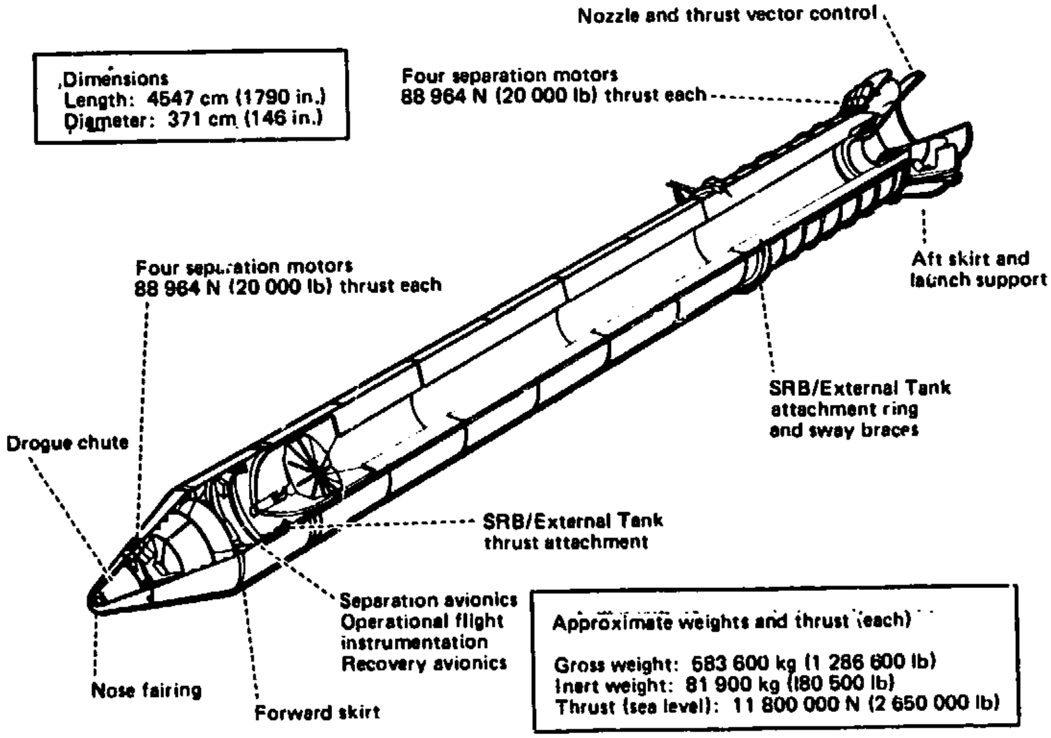


Figure 2-4.-- Space Shuttle Solid Rocket Booster.

The heart of the SRB is the reusable SRM. The motor consists of 11 steel case segments assembled into four propellant-loaded segments: a forward segment, two interchangeable cylindrical center segments, and an aft segment incorporating provisions for nozzle attachment and attachment points to the External Tank. The propellant is case-bonded polybutadiene acrylonitrile (PBAN) composite propellant (70 percent ammonium perchlorate, 16 percent aluminum, and 14 percent PBAN binder). A single movable nozzle provides for thrust vector control. The nozzle position is controlled by two hydraulic actuators supplied by a pair of hydrazine-fueled turbine-driven hydraulic power units mounted in the aft skirt.

2.2.3 External Tank

The External Tank (fig. 2-5) contains the propellants for the Orbiter's main engines: liquid hydrogen fuel and liquid oxygen oxidizer. All fluid controls and valves (except the vent valves) for operation of the main propulsion system are located in the Orbiter to minimize throw-away costs. Antivortex and slosh baffles are mounted in the oxidizer tank to minimize liquid residuals and to damp fluid motion. Five lines (three for fuel and two for oxidizer) interface between the External Tank and the Orbiter. All are insulated except the oxidizer pressurization line. Liquid-level point sensors are used in both tanks for loading control. The approximate dimensions, tank weight, and propellant loadings are cited in figure 2-5.

The External Tank is constructed of aluminum alloy skins with support or stability frames as required. Spray-on foam insulation is applied to the complete outer surface of the External Tank, including the sidewalls and the forward bulkheads. This spray-on ablator is applied to all protuberances, such as attachment structures, because shock impingement causes increased heating to these areas.

2.3 Phases of the Space Shuttle Program

The Space Shuttle Program consists of two distinct phases, development and flight operations. The Space Shuttle is currently in its development phase; the flight operations phase should begin in 1979. The development phase includes facility activation, modification or construction and design, production, test, and delivery of Space Shuttle flight test articles. The flight operations phase covers the production and delivery of required Space Shuttle flight articles and all orbital flights from the John F. Kennedy Space Center (KSC), Florida; and Vandenberg Air Force Base (VAFB), California. A timetable for major activities in the development and flight operations phases is given in table 2-1. The following subsections summarize development and flight operations phase activities of the Space Shuttle Program.

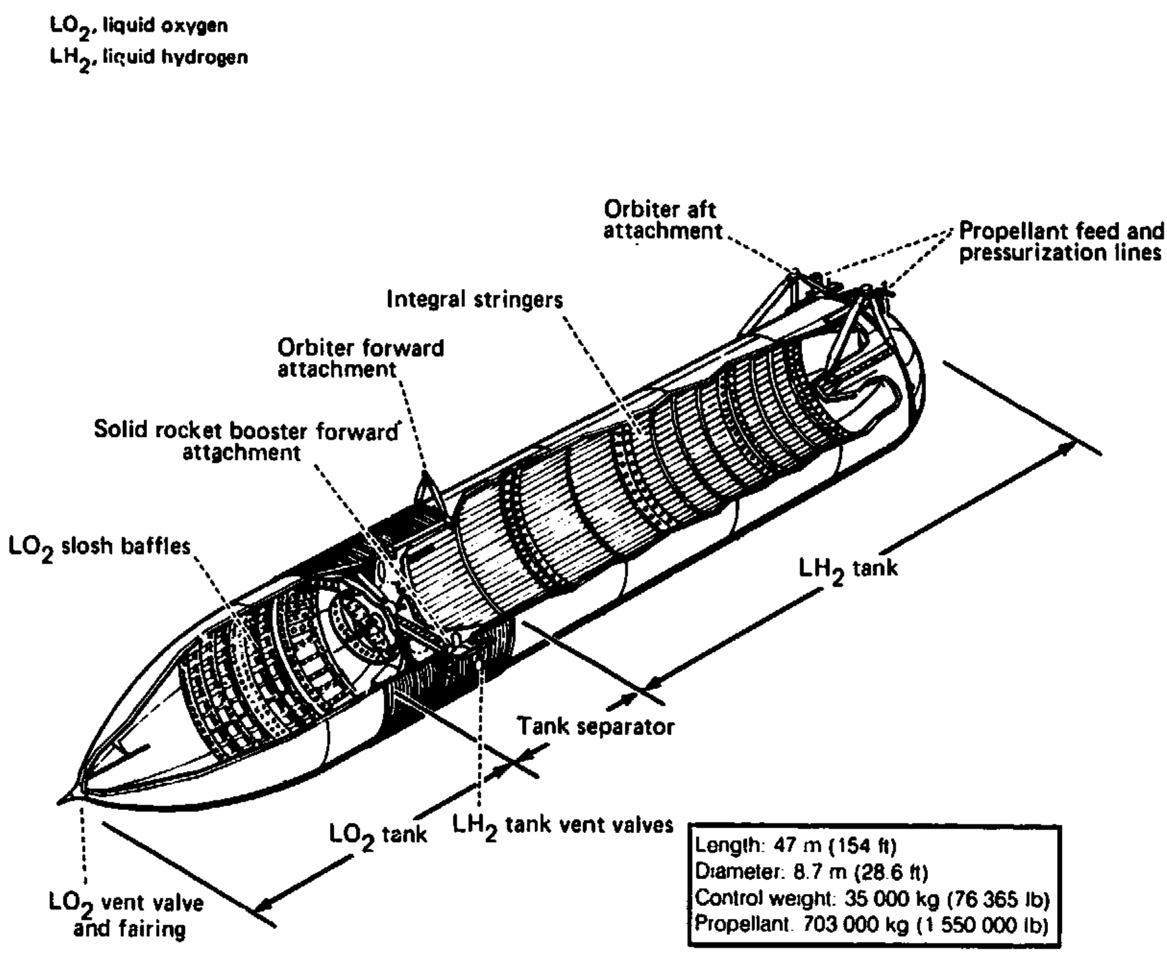
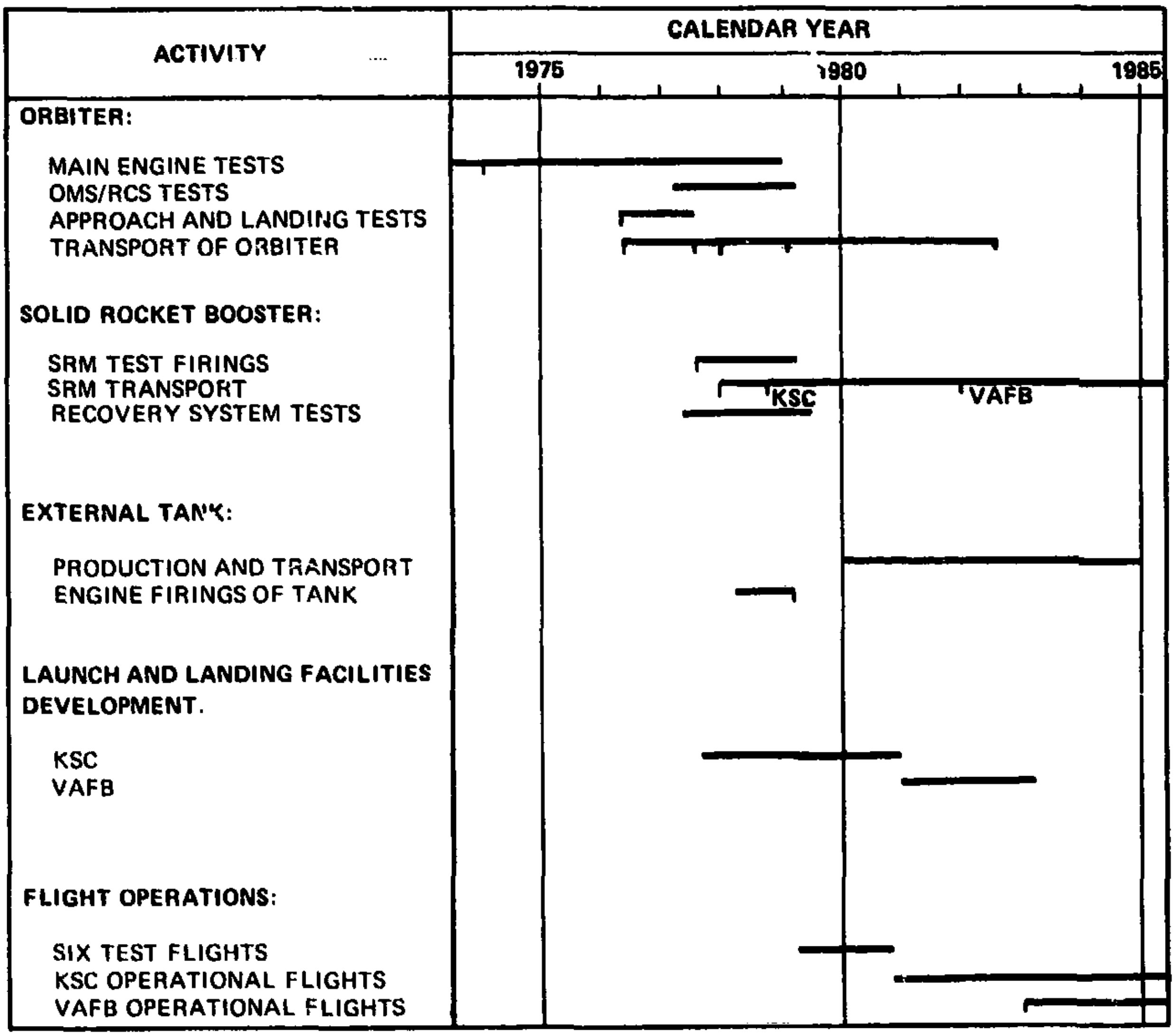


Figure 2-5.-- External Tank.

TABLE 2-1.-- TIMETABLE FOR MAJOR SPACE SHUTTLE PROGRAM ACTIVITIES



2.3.1 Development Phase

Development of the Space Shuttle vehicle is managed by NASA, with most of the development work being performed by various aerospace contractors. NASA Headquarters in Washington, D.C., and NASA's Lyndon B. Johnson Space Center (JSC) in Houston, Texas, have responsibility for the overall management of the Space Shuttle Program. NASA/JSC is also responsible for the development of the Orbiter. NASA/MSFC in Huntsville, Alabama, is responsible for development of the Space Shuttle's main engine, the External Tank, and the SRB. NASA/KSC and the DOD/VAFB will be responsible for launch and recovery operations.

The names of the major contractors that support NASA in the design, development, test, and evaluation (DDT&E) of the Space Shuttle vehicle and its related systems or facilities are cited in figure 2-6. The NASA-owned or contractor facilities at which major production and test activities will be performed are identified in figure 2-7. Key activities performed at each site are also noted in the figure.

The major development areas are Orbiter, SRB, External Tank, crew training, and launchsite development. The Space Shuttle test program includes vibration tests, main propulsion system and engine tests, avionics system tests, SRB tests, structural tests of the External Tank and the Orbiter, and the approach and landing tests (ALT's).

2.3.1.1 Orbiter Development

NASA/JSC is responsible for the development of the Orbiter. The Space Division of Rockwell International, located in California, is the prime contractor. Rockwell has subcontracted development and fabrication of major and minor subsystems to various contractors throughout the United States. Figure 2-8 shows the distribution of Orbiter subcontracts. Many of the subcontractors are expected to participate in the Space Shuttle Program during the flight operations phase.

Two Orbiters will be constructed as part of the DDT&E program. Major milestones in the program include production rollout of Orbiter-101 (September 1976) and Orbiter-102 (1978), the beginning and completion of the ALT program (1977 -- Orbiter-101 carried aloft piggyback and released by a Boeing 747 carrier aircraft), main engine test firings (1977), and the first manned orbital flight (1979).

Development activities associated with the Orbiter include the DDT&E of the Orbiter subsystems: Orbiter main engine tests, OMS and RCS engine tests, transport of the Orbiter, ALT's, and flight readiness firing.

2.3.1.1.1 Main Engine

Managing the development of the Space Shuttle's main engine is the responsibility of NASA/MSFC. The development and production contract for

MAIN ENGINES

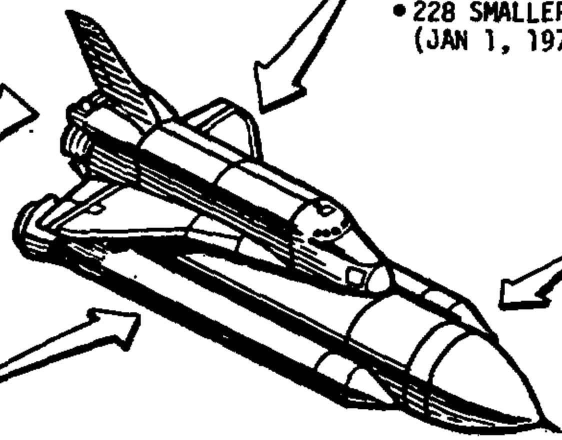
ROCKWELL - ROCKETDYNE DIV
CALIFORNIA

- CONTROLLER-HONEYWELL: MINN & FLA
- HYDRAULIC ACTUATORS-HYDRAULIC RESEARCH: CAL

VEHICLE INTEGRATION & ORBITER

ROCKWELL - SPACE DIV
CALIFORNIA

- 21 SUBCONTRACTS OVER $10M
- 62 SUBCONTRACTS $1-10M
- 228 SMALLER SUBCONTRACTS (JAN 1, 1976 STATUS*)



EXTERNAL TANK

MARTIN-MARIETTA
COLORADO & LOUISIANA

- INTERTANK STR - AVCO: TENN
- TOOLING - LTV: TEX
- GORES & OJIVES - AIRCRAFT HYDROFORMING: CAL
- LH_2 BARREL PANELS - REYNOLDS METAL: ILL

SOLID ROCKET MOTOR

THIOKOL
UTAH

- MOTOR CASING - ROHR: CAL
- CASE FORGINGS - LADISH: WISC
- NOZZLE METAL PARTS - KAISER: CAL
- NOZZLE FORGINGS - AMERICAN WELDING: OH

OTHER MAJOR CONTRACTORS

- KSC DESIGN ENGINEERING & SUPPORT - PRC: FLA
- LAUNCH PROCESSOR SYSTEM SOFTWARE DEVELOPMENT - IBM: NY
- ENGINEERING OPERATIONS SUPPORT - MDAC: MO
- CARRIER AIRCRAFT - AMERICAN AIRLINES: OKLA
- ORBITER SOFTWARE PROGRAMMING-IBM: TEX
- SHUTTLE TRAINING AIRCRAFT-GRUMMAN: NY

*SOME CONTRACTS INVOLVE MULTIPLE ITEMS

Figure 2-6.-- Major contractors in the Space Shuttle Program.

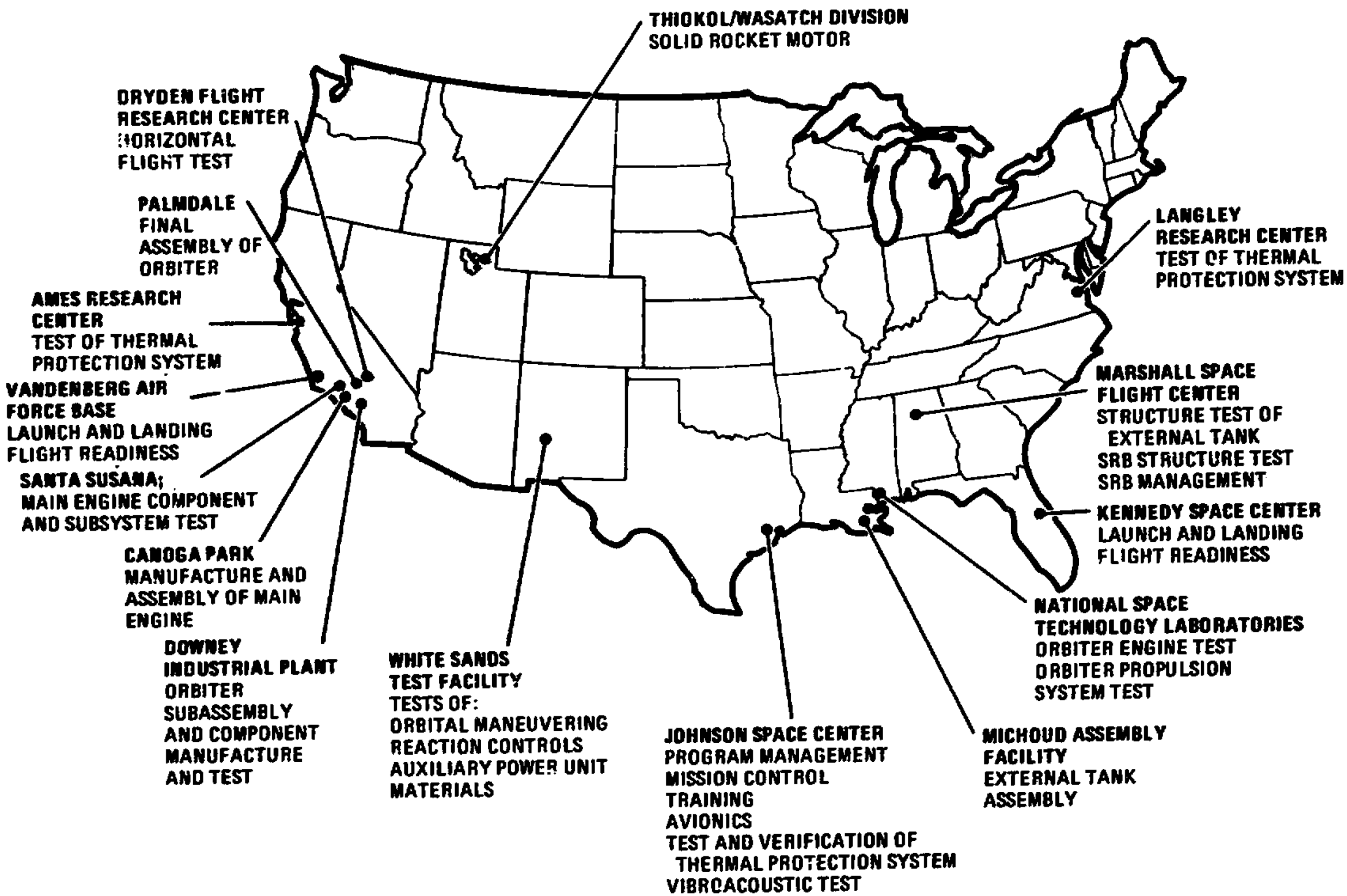


Figure 2-7.-- Locations of the Space Shuttle facilities.

MAJOR AWARDS*

• FLIGHT CONTROL SYSTEMS	HONEYWELL-MINNESOTA/FLORIDA
• DATA PROCESSING & SOFTWARE REQUIREMENTS	IBM-NEW YORK
• OMS/RCS AFT INTEGRATED MODULE	MDAC-MISSOURI
• VERTICAL STABILIZER	REPUBLIC-NEW YORK
• WING	GRUMMAN-NEW YORK
• MID-FUSELAGE	GENERAL DYNAMICS-CALIFORNIA
• REUSABLE SURFACE INSULATION	LOCKHEED-CALIFORNIA
• LEADING EDGE THERMAL PROTECT. SUBSYSTEM	LTV-TEXAS
• ATM. REVITALIZATION-THERMAL HEAT TRANSPORT	HAMILTON STANDARD-CONNECTICUT
• FUEL CELL POWER PLANT	PRATT & WHITNEY-CONNECTICUT
• ONBOARD COMPUTER INPUT/OUTPUT BUFFER	IBM-NEW YORK
• POWER REACTANT STORAGE ASSEMBLY	BEECH AIRCRAFT-COLORADO
• ORBITAL MANEUVERING SYS (OMS) ENGINES	AEROJET-CALIFORNIA
• AUXILIARY POWER UNIT	SUNDSTRAND-ILLINOIS
• MULTIPLEXER DEMULTIPLEXER	SPERRY-ARIZONA
• REACTION CONTROL SYS (RCS) THRUSTERS	MARQUARDT-CALIFORNIA
• CARRIER AIRCRAFT MODIFICATION	BOEING-WASHINGTON
• STRUCTURAL TEST	LOCKHEED-CALIFORNIA
• S-BAND SYSTEM	TRW-CALIFORNIA

TYPICAL OTHER AWARDS

• AUTO LAND	SPERRY-ARIZONA
• WINDOWS/WINDSHIELDS	CORNING-NEW YORK
• INERTIAL MEASUREMENT UNIT	SINGER-KEARFOTT-NEW JERSEY
• ANALOG COMPUTER SYSTEM	ELECTRONICS ASSOC-NEW JERSEY
• DIGITAL COMPUTER SYSTEM	XEROX-CALIFORNIA
• FUEL CELL POWER PLANT	PRATT & WHITNEY-CONNECTICUT
• MAIN & NOSE LANDING GEAR STRUCTURE	MENASCO-CALIFORNIA
• WHEELS & BRAKES	B.F. GOODRICH-OHIO
• DATA ACQUISITION SYSTEM	MODULAR COMPUTER SYSTEMS-FLORIDA
• SERVO ACTUATORS	HYDRAULIC RESEARCH & MFG.-CALIFORNIA
• MULTIPLEXER INTERFACE ADAPTER	SINGER-KEARFOTT-NEW JERSEY
• RUDDER/SPEED BRAKE ACTUATOR	SUNDSTRAND-ILLINOIS
• SMOKE DETECTION SYSTEM	CELESCO INDUSTRIES-CALIFORNIA
• MAIN ENGINE GIMBAL ACTUATOR	MOOG, INC.-NEW YORK
• NAVIGATION SET	AIL/CUTLER-HAMMER-NEW YORK
• POTABLE & WASTE TANKS	METAL BELLOWS CO.-CALIFORNIA
• RCS TANKS	MARTIN-COLORADO
• TACAN	HOFFMAN ELECTRONICS-CALIFORNIA
• PULSE CODE MODULATOR	HARRIS ELECTRONICS-FLORIDA
• RATE GYRO ASSEMBLY	NORTHROP-MASSACHUSETTS
• ATTITUDE DIRECTION INDICATOR	LEAR SIEGLER-MICHIGAN
• MASTER TIMING UNIT	WESTINGHOUSE ELECTRIC-MARYLAND
• ENGINE INTERFACE UNIT	CONRAC CORP.-NEW JERSEY
• AMMONIA BOILER	FAIRCHILD STRATOS-CALIFORNIA
• THERMAL CIRCUIT BREAKERS	AIKEN INDUSTRIES-MICHIGAN
• POWERSTATIC INVERTER	WESTINGHOUSE-OHIO
• PROPELLANT SENSORS	SIMMONDS PRECISION-VERMONT
• WASTE COLLECTION SYSTEM	GENERAL ELECTRIC-PENNSYLVANIA
• GROUND MAINTENANCE & OPERATIONS SUPPORT	AMERICAN AIRLINES-OKLAHOMA

*OVER $10M

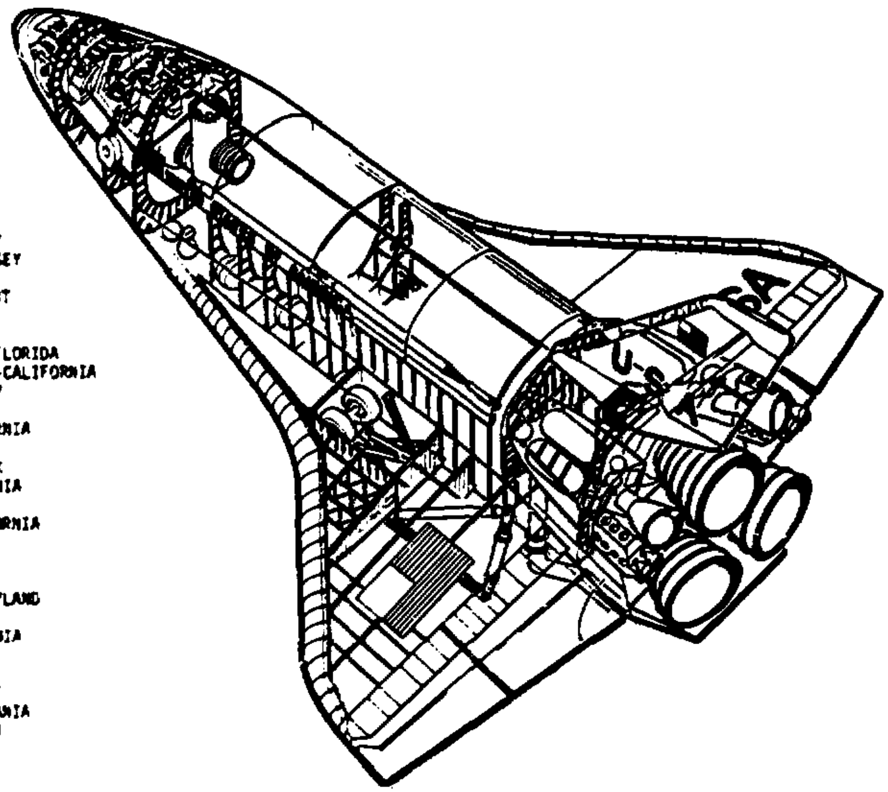


Figure 2-8.-- Distribution of Orbiter subcontracts.

the oxygen/hydrogen main engine was awarded to the Rocketdyne Division of Rockwell International. Under the current contract, 10 developmental and 7 production engines are to be built at Rocketdyne's Canoga Park, California, facility.

To develop and qualify the main engine for manned Space Shuttle flight, personnel at the National Space Technology Laboratories (NSTL) in Bay St. Louis, Mississippi, and the Santa Susana Test Facility in Santa Susana, California, have been conducting static test firings of the engine (see fig. 2-7). The test programs and associated environmental effects are described in some detail in an environmental impact statement for each site (refs. 1-4 and 1-2, respectively). Existing facilities, suitably modified, are being used at both sites; these test programs have been under way for some time.

2.3.1.1.2 Engine Tests of the Orbital Maneuvering and Reaction Control Systems

The Space Shuttle OMS and RCS will be contained in integrated modules being developed by McDonnell-Douglas Astronautics Company (MDAC) in St. Louis, Missouri. Test firings of the OMS and RCS engines will be conducted as the White Sands Test Facility at Las Cruces, New Mexico.

Both the OMS and RCS engines use nitrogen tetroxide (oxidizer) and MMH (fuel) propellants which are hypergolic (i.e., which ignite spontaneously upon contact with each other). Hypergolic engines have been tested at the White Sands Test Facility since 1964, and the facility is well equipped to handle the OMS and RCS tests.

2.3.1.1.3 Transport of the Orbiter

The Orbiter is not designed for powered atmospheric flight (except on ascent to Earth orbit); therefore, it must be transported on carrier vehicles between production facilities, test sites, launchsites, and landing sites. There are two types of carrier vehicles, one for ground transport and one for air transport.

The Orbiter will be transported from the Palmdale Assembly Facility to the Edwards Air Force Base (EAFB)/Dryden Flight Research Center (DFRC). For this overland transport of approximately 56 km (35 miles), the Orbiter will be mounted on a commercial transporter, which can be towed by a standard heavy-duty truck tractor over standard roads. Figure 2-9 shows the

Orbiter mounted on a commercial transporter, and figure 2-10 shows the overland route between the Palmdale Assembly Facility and EAFB. This action and the environmental effects thereof are described in reference 1-3. The first transport of Orbiter-101 was accomplished in March 1977. The Orbiter-101 will be returned to Palmdale via the same route. At later dates, one-way transits of all five Orbiters will occur. Overland transport at other locations, such as at KSC, VAFB, MSFC, and DFRC, will require a powered transporter to pull the Orbiter while supported by its landing gear. Transport at these locations will occur entirely on government property.

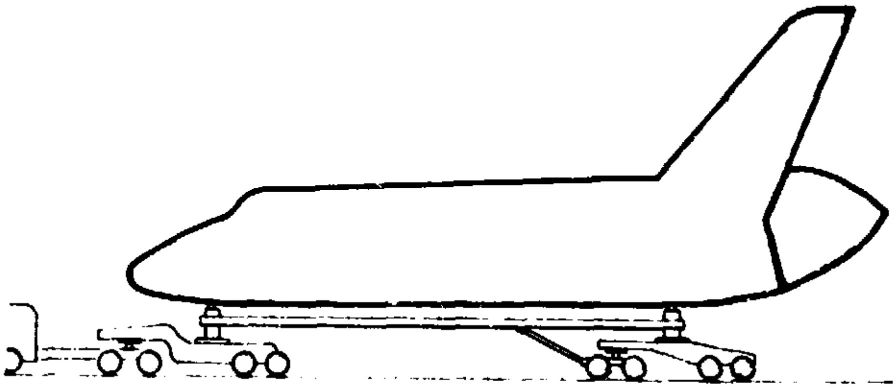


Figure 2-9.-- Orbiter supported on commercial transporter.

The primary means of long-distance transport is by mounting the Orbiter piggyback on a modified Boeing 747 aircraft as shown in figure 2-11. The Boeing 747 will be used to ferry the Orbiter to and from the following sites: EAFB/DFRC, MSFC, KSC, and VAFB. During Space Shuttle development, the Boeing 747 Space Shuttle carrier aircraft is being used extensively in the Orbiter ALT program. At present, three ferry flights are planned before the start of the Space Shuttle orbital flight operations phase:

- Ferry flight of Orbiter-101 from EAFB to MSFC for ground vibration tests.
- Ferry flight of Orbiter-102 from EAFB to KSC for the first manned orbital flight of the Space Shuttle.
- Ferry flight of Orbiter-101 from MSFC to EAFB for subsequent ground transport to the Palmdale Assembly Facility.

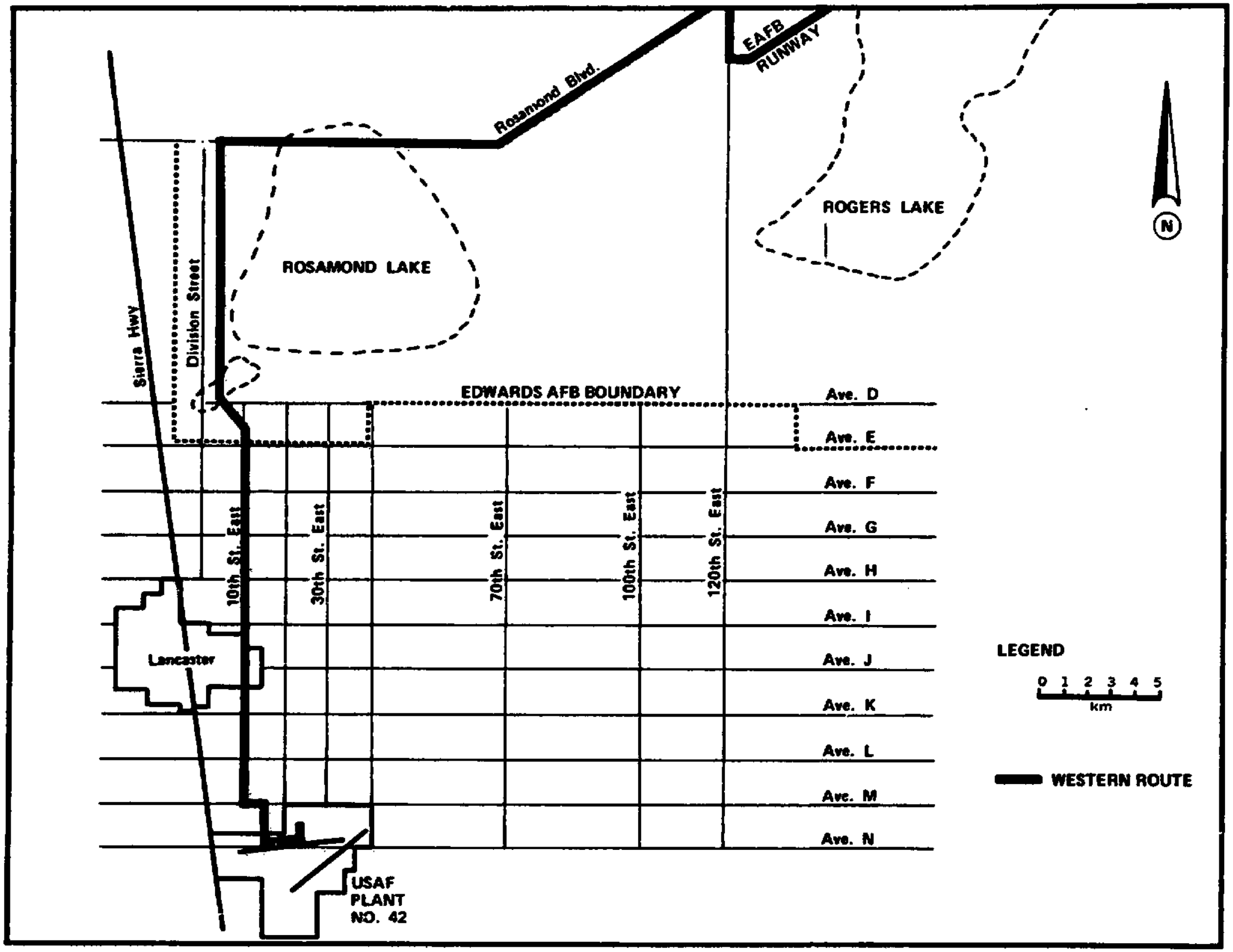


Figure 2-10.-- Overland transport route of the Orbiter from Palmdale to Edwards Air Force Base.

Figure 2-11.-- Orbiter transported atop the Space Shuttle carrier aircraft.

2.3.1.1.4 Approach and Landing Test (ALT) Program

The primary objectives of the ALT program were to demonstrate the approach and horizontal landing capability of the Orbiter and the ferry operations of the Orbiter atop a Boeing 747 (see fig. 2-11). The ALT program involved five types of flight tests: carrier aircraft testing, captive inert Orbiter testing (unmanned), captive active Orbiter testing (manned), Orbiter free-flight testing (manned), and ferry operations testing (unmanned). The program was conducted at the EAFB/DFRC.

The Boeing 747 Space Shuttle carrier aircraft has completed the program of carrier aircraft testing; the program of testing the mated carrier aircraft and Orbiter with the latter in an unmanned, inert configuration is also now finished.

During 1977, captive active Orbiter tests and Orbiter free-flight and landing tests involving mid-air separation from the Space Shuttle carrier aircraft were conducted. The Orbiter landing tests involved the ascent of the Orbiter (manned) Space Shuttle carrier aircraft followed by a mid-air separation of the Orbiter from the aircraft and a free-flight glide of the Orbiter to a runway landing on Rogers Lake bed at EAFB. This test series of about eight flights has been completed.

2.3.1.1.5 Flight Readiness Firing

In preparation for the first manned orbital flight of the Space Shuttle vehicle, a flight readiness firing of the Orbiter's main engines may be required. The Shuttle vehicle that will make the first manned orbital flight will be placed into launch position on Pad A at KSC Space Launch Complex 39. The flight readiness firing will last 20 sec and will provide prelaunch validation of the flight and ground hardware and software. Techniques and procedures for propellant loading and launch countdown, including safing techniques, will also be verified. After the flight readiness firing, the Shuttle vehicle will remain on the launch pad, and final preparations for the first orbital flight will begin.

2.3.1.2 Development of the Solid Rocket Booster

NASA/MSFC has the overall responsibility for the development of the Space Shuttle SRB (see fig. 2-7). The key milestones in the SRB project are the successful static test firings of the SRM's at the Thiokol/Wasatch Division in Promontory, Utah, and the delivery of SRB hardware to KSC for the first manned orbital flight of the Space Shuttle. All aspects of the SRB project reflect the knowledge and experience gained in the previous fabrication and processing of large SRM's and their components (e.g., 120-, 156-, and 260-inch SRM's). The SRB development program is unique in that the SRB has been designed to be recoverable and reusable. Current plans are to have each SRB flown in at least 20 missions.

The development of the SRB is being accomplished by industrial and governmental agencies. NASA/MSFC has played a major role in the design of the SRB and its subsystems. Numerous contractors throughout the nation are supporting the effort (see fig. 2-12). Many of these same contractors are expected to continue to participate in the SRB project during the operational flight phase of the Space Shuttle Program.

Major development activities associated with the SRB project include the DDT&E of the SRM, the separation motor, and the recovery system. The Space Shuttle SRM project was awarded to the Wasatch Division of the Thiokol Corporation located near Promontory, Utah. The project involves the processing of 19 SRM's and static testing of 7 SRM's at Thiokol/Wasatch Division, the delivery of 12 SRM's to NASA/KSC, and the delivery of 2 inert and 3 empty SRM's to NASA/MSFC.

To develop and qualify the Space Shuttle SRM for manned Space Shuttle flights beginning in 1979, seven SRM's have been scheduled for horizontal static test firing at the remotely located Thiokol/Wasatch plantsite. The SRM static test firings have been scheduled for an 18-month period beginning in July 1977 and lasting through December 1978.

The 12 SRM's, which will be shipped from Thiokol/Wasatch to KSC to support the first six Space Shuttle orbital flights, will be transported via rail as individual motor segments. The segments will have covers over the open ends of the grain, and each segment will be encapsulated by a shroud. The shroud is designed to protect the segment from the elements. Upon recovery of spent SRM's at KSC, the empty case segments will be returned, via rail, to Thiokol for subsequent refurbishment and future reuse.

The booster separation motor (BSM) program consists of processing, testing, and delivering BSM's in support of the Space Shuttle Program. The program, under the direction of MSFC, involves the processing of 144 and static testing of 38 BSM's at United Technologies Corporation/Chemical Systems Division, Sunnyvale, California; the delivery of 106 BSM's (96 for Shuttle flights and 10 spares) to KSC, Florida; and the processing and delivery of 4 inert BSM's to MSFC.

NASA/MSFC, in conjunction with Martin Marietta Corporation, Pioneer Parachute Company, and the DFRC, plans to test the SRB recovery parachutes near El Centro, California. These tests are necessary for the development of a reliable SRB recovery system. The tests (13 in all) will be conducted at the National Parachute Test Range during 1977 and 1978 by dropping a 23 000-kg (50 000-lb) cast iron mass and parachute system at approximately 6000 m (20 000 ft) from a B-52 aircraft. The aircraft employed will take off and land from EAFB. The mass and parachute system will be mated to the B-52 in a similar fashion as was done with previous X-15 tests. Adequate safety precautions will be taken to avoid premature release of the mass and the parachute system.

2.3.1.3 Development of the External Tank

The External Tank is the only major element of the Space Shuttle system that is expendable. The External Tank is released from the Orbiter

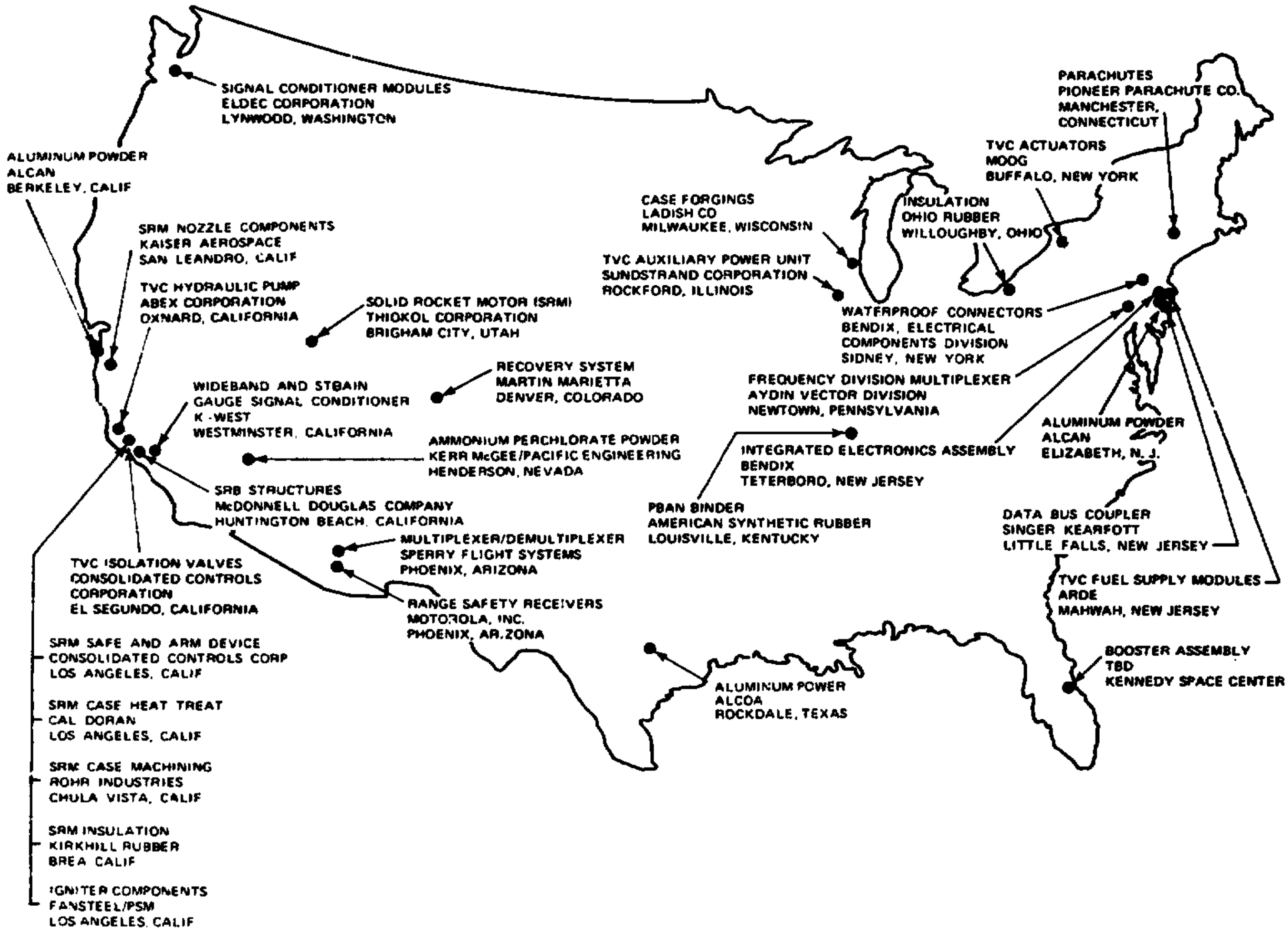


Figure 2-12.-- Distribution of major solid rocket booster/motor development contractors.

approximately 30 sec after main engine cutoff. It breaks up and impacts downrange in a remote ocean area (the Indian Ocean for KSC launches and the South Pacific Ocean for VAFB launches). NASA/MSFC is responsible for development of the External Tank. The contract for the development and production of the External Tank has been awarded to the Aerospace Division of Martin Marietta Corporation of Denver, Colorado. However, all tank production will be carried out at NASA/MAF (see figs. 2-6 and 2-7). Facility location and availability and the existence of waterway connections to MSFC and KSC were major factors in NASA's selection of the MAF as the site for manufacturing the External Tank. In addition, a portion of the investment related to Saturn vehicle production, such as tooling and special building facilities, could be salvaged to be reused for External Tank production.

Nine External Tanks and several other smaller test articles will be produced at MAF during the Space Shuttle development phase. The MAF contains 34 manufacturing fixtures and more than 685 special large tools. The number of tools will increase with production rates. Most of the major tools have been newly designed and produced by large U.S. aerospace manufacturers. Smaller tooling left from Saturn is also being utilized. During the production of External Tanks, processes will involve cleaning and degreasing of External Tank parts with trichloroethylene, spray painting, and the application and use of polyurethane ablative insulation on the tank's outer surface.

During the development phase, a series of tests on the External Tank will be made. Two tanks will be tested at MSFC and one at the NSTL. Six tanks will be shipped to KSC for use as flight units. The other smaller test articles will be delivered to MSFC for testing. Some initial testing of the components and tanks will be conducted at the MAF.

External Tanks produced at MAF during the development phase of the Space Shuttle Program will be transported by barge along existing waterways to KSC, MSFC, and NSTL. Two barges, each capable of transporting one External Tank, are available to deliver External Tanks to KSC. Two additional barges are suitable for carrying test articles to MSFC or NSTL.

2.3.1.4 Crew Training

A Space Shuttle crew flight training program is currently under way to prepare astronaut crewmembers for Space Shuttle flight operations. NASA/JSC has management responsibility for the program. Under a JSC contract, Grumman Aerospace Corporation of Bethpage, New York, has delivered two Space Shuttle training aircraft (modified Gulfstream II aircraft). Each training aircraft is configured to provide Orbiter pilots with a realistic simulation of cockpit motions, visual cues, and handling qualities while at the same time to match the Orbiter atmospheric descent trajectory from 11 000-m (35 000-ft) altitude to touchdown. The training aircraft simulates Orbiter glide characteristics by the use of its control surfaces and the thrust reversal of its engines. The training aircraft vehicle will provide simulation capability to satisfy the following primary objectives: training Orbiter pilots, verifying Orbiter pilot flight procedures during atmospheric flight maneuvers, supporting the ALT program, and supporting

the verification of the microwave landing systems at the test sites and launchsites.

The training aircraft are based at Ellington Air Force Base located approximately 11 km (7 miles) northwest of NASA/JSC. JSC utilizes 15 buildings at Ellington Air Force Base for aircraft maintenance, cleaning and repair operations, and astronaut training for flying proficiency.

The primary training area for Orbiter pilot training will be the Northrop Strip at White Sands, New Mexico. During training maneuvers, all flights are expected to originate and terminate at Ellington Air Force Base.

In addition to the primary training area, training operations will be conducted at three sites: EAFB, VAFB, and KSC. The training aircraft will be based at the site scheduled for training exercises, except that at KSC the training aircraft will be based at Patrick Air Force Base, Florida. Training areas will be used to provide training for the ALT program (at EAFB) and for specific Space Shuttle mission-oriented landing and launch abort training (at VAFB and KSC).

2.3.1.5 Launchsite Development

Early in the Space Shuttle Program, two launchsites were chosen, KSC and VAFB. Two launchsites are required to accommodate the wide variety of space missions that will be flown with the Space Shuttle (see section 2.3.2.3). Range safety constraints (no overflight of populated land areas during launch) require that polar and Sun-synchronous missions be flown from VAFB and that near-equatorial, geosynchronous, and planetary missions be flown from KSC. NASA is currently preparing Space Shuttle facilities at KSC; the USAF will be providing operational Space Shuttle launch facilities at VAFB beginning in late 1982.

Currently, expendable launch vehicles (such as Scout, Delta, Thor, Atlas, and Titan) are launched from KSC and VAFB. A significant base of existing facilities at the two launchsites will be used to support the Space Shuttle missions of the 1980's. At KSC, Apollo-Saturn Space Launch Complex 39 (now a national historic site) is being modified for Space Shuttle operations. At VAFB, Space Launch Complex 6, which was originally constructed for launching the Titan III-M expendable launch vehicle, will be extensively modified to support Space Shuttle operations. Completion of the construction and modification of the two Space Shuttle launchsites will be required to support the first Shuttle launches at each facility: March 1979 at KSC and December 1982 at VAFB.

During the launchsite development phase for the Space Shuttle Program, facilities at KSC and VAFB will be constructed, modified, or expanded so that 40 flights per year from KSC and 20 flights per year from VAFB can be accommodated. Construction of new facilities involve the following activities: clearing and removing vegetation from the construction site; rough-grading the exposed soil; excavating for below-grade rooms, foundations, and underground utility lines; grading and finishing surface drainage systems; preparing and pouring concrete; erecting the structure;

installing pavement; landscaping the area; emplacing fences; and cleaning up and disposing of construction debris. Modification of existing structures will range from rearrangement of interior partitions to significant facility expansions. Modification activities may involve any or all of the activities required for construction of new facilities. Activation of facilities will encompass equipment installation, equipment interconnection and checkout, testing of interfacility networks, the dredging of existing barge channels at KSC, and maintenance of the facilities from the completion of construction until the initiation of Space Shuttle operations.

Information on Space Shuttle development and operations at the two launchsites is provided in two environmental impact statements (refs. 1-5 and 1-9).

2.3.2 Flight Operations Phase

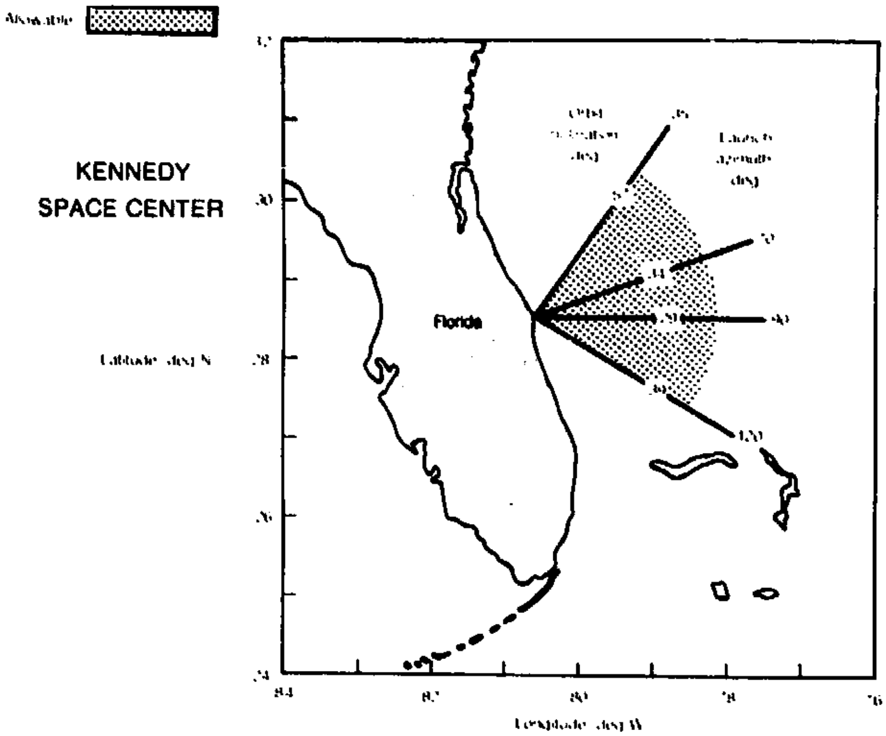
This section describes the entire Space Shuttle orbital test flight and operational phase which extends through the decade of the 1980's and into the 1990's and includes Space Shuttle ground and flight operations, missions, hardware production and transportation, and propellant production and transportation.

The first Space Shuttle orbital test flight is scheduled to be launched from KSC in mid-1979. Five additional test flights launched from KSC are planned before the start of operational flights, scheduled to begin in mid-1980. Because of launch azimuth restrictions, which preclude space vehicle launch overflight of populated land masses, a second Space Shuttle launchsite is required to meet the demands of all missions. VAFB is expected to be operational at the end of 1982. Easterly launches will be conducted from KSC; southerly (polar) launches will be conducted from VAFB (see fig. 2-13).

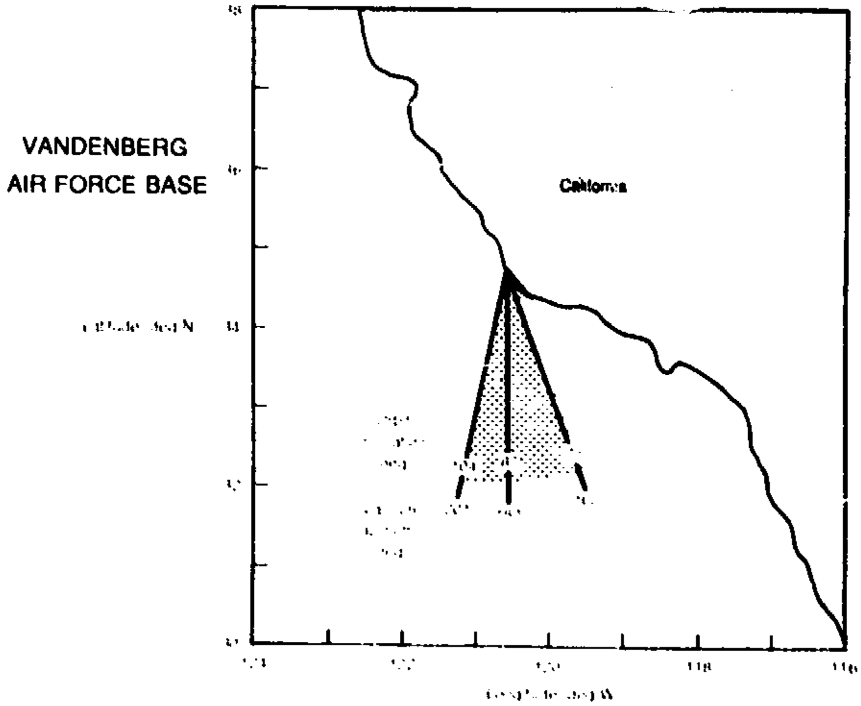
2.3.2.1 Ground Operations

Space Shuttle ground operations include all actions from the time the Orbiter comes to rest on the runway until it is relaunched. Space Shuttle operations will be conducted from KSC and VAFB. The operations at each location are similar; but there are differences, particularly in ground operations. For example, at KSC the Orbiter, the SRB, and the External Tank will be mated in a vehicle assembly building, and the mated vehicle will then be transported to the launch pad. At VAFB, the vehicle elements will be transported to the pad separately and mated on the pad. The KSC and VAFB operations are described in references 1-5, 1-9, and 2-2.

Ground operations at KSC will be established as part of the Space Shuttle Orbital Flight Test Program. There will be a number of differences between ground operations during the flight test program and during the operational phase. In particular, the operational ground turnaround will consist of less testing, and the total turnaround time will be reduced.



(a) From Kennedy Space Center.



(b) From Vandenberg Air Force Base.
Figure 2-13.-- Orbit inclinations and launch azimuths.

Testing activities will be gradually reduced during the course of the flight test program as confidence is achieved.

The Orbital Flight Test Program begins with delivery of the Orbiter-102 following completion of final manufacturing ground test and checkout operations. The current plan is to use the Orbiter-102 in all development orbital flight tests. After the flight test program, the Orbiter-102 will be modified as required for the operational phase of the Space Shuttle Program. The remaining Orbiters will arrive for use during the operational period.

The operational ground checkout philosophy for the Space Shuttle elements can be summarized as follows: (1) the elements (Orbiter, SRB, External Tank) are checked out and verified to be ready for flight before assembly/integration; (2) checkout is conducted after mating of the elements and between the Space Shuttle vehicle and ground equipment; and (3) there will be virtually no additional checkout at the launch pad (however, some interfaces must be verified at the pad, and some flight critical systems must be verified prior to launch).

The planned flow of the Space Shuttle system operational ground turnaround at KSC is shown in figure 2-14. Details of the KSC ground operations cycle are discussed in references 1-5 and 2-2.

2.3.2.2 Flight Operations

The Space Shuttle Orbital Flight Test Program is scheduled to begin at KSC in 1979 with the first manned orbital flight scheduled for April. Five additional test flights will follow -- three in 1979 and two in 1980. The first flight from VAFB is expected at the end of 1982.

The six orbital test flights from KSC will provide verification of the Space Shuttle system. Test flights will differ from operational flights in that added safety precautions will be taken to protect the crew and to minimize the possibility of damage to Shuttle systems. Additional test and monitoring equipment will be onboard, and mission plans will emphasize system testing.

After each of the first four flights, the Orbiter will land at EAFB (site of the ALT program) rather than at KSC. This will provide the Space Shuttle with a larger landing area (the dry bed of Rogers Lake at EAFB) than is available at KSC. In the fifth and sixth flights, the Orbiter will land at KSC. During the six orbital test flights, the Orbiter will be equipped with emergency ejection seats for the crew. On successful completion of the flight test program, the ejection seats will be removed.

The first operational Space Shuttle mission is scheduled to be launched from KSC in May 1980; VAFB flight operations are to begin in December 1982. The Space Shuttle operational flight phase of both sites is currently planned to last through the 1980's. By the mid-1980's, launch rates are expected to reach a total of 60 per year, 40 per year at KSC and 20 per year at VAFB.

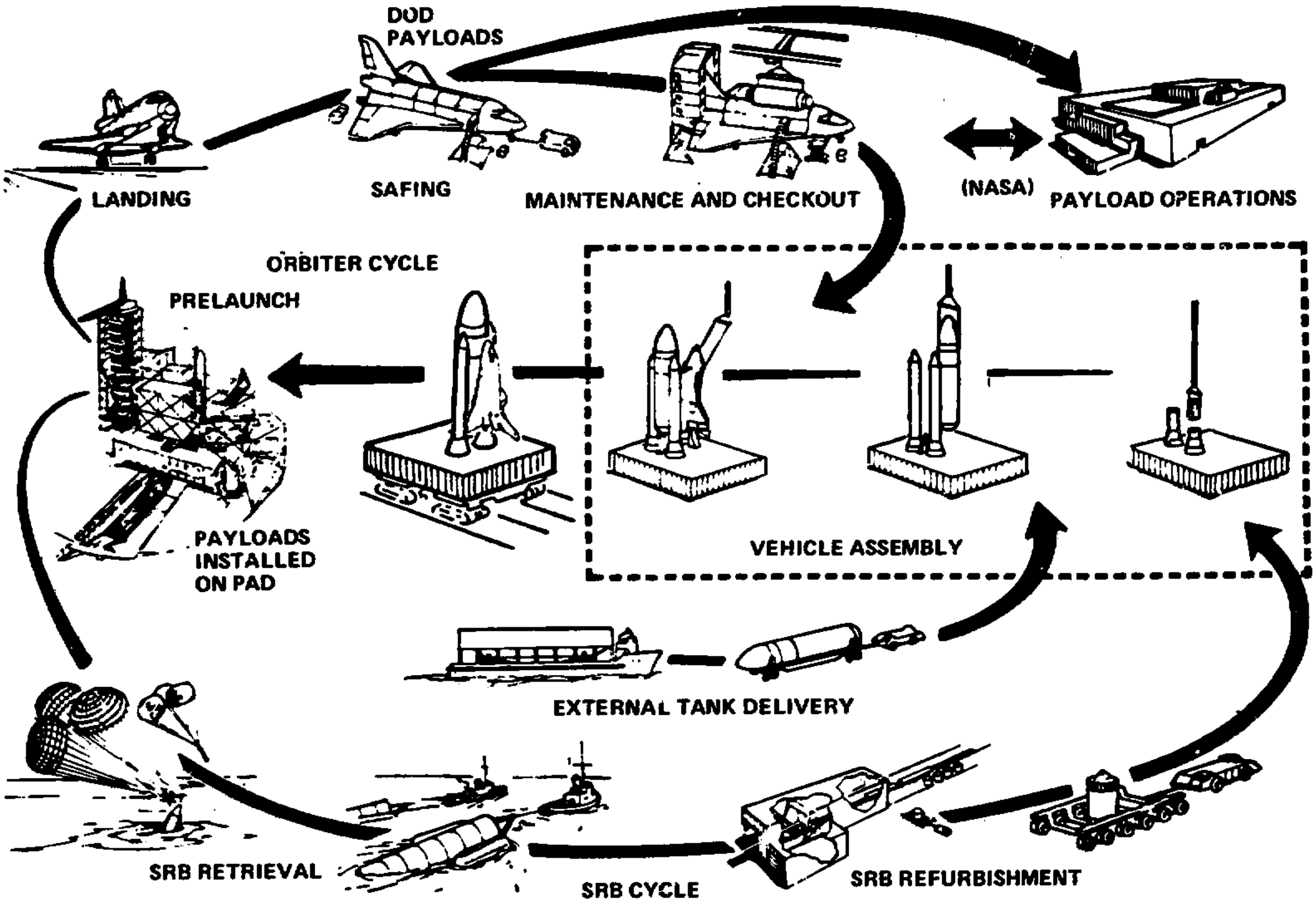


Figure 2-14.-- Operational turnaround flow for the Space Shuttle.

Figure 2-15 shows the profile of a typical Space Shuttle mission. Launch begins with the ignition of the three Space Shuttle main engines (attached to the Orbiter), followed by ignition of the two SRM's. All engines operating together produce a combined thrust of approximately 28 million N (6.4 million lb). The gross lift-off mass for a typical mission will be about 2.0 million kg (4.4 million lb). After a short vertical rise from the launch pad, the vehicle pitches over onto its ascent path. The Space Shuttle vehicle reaches an altitude of 44 km (145 000 ft) 46 km (29 miles) downrange from the launchsite, approximately 124 sec after lift-off (exact flight profiles are specific to each mission), where the SRM's burn out. Eight BSM's on each SRB (four forward and four aft) are used to separate the SRB from the Orbiter and the External Tank. Following separation, SRB parachutes are deployed; and the SRB's descend to a splashdown in the ocean approximately 240 km (150 miles) downrange from the launchsite, where the SRB's and parachutes are recovered for refurbishment and reuse. Space Shuttle ascent continues, propelled by the Space Shuttle main engines until main engine cutoff, which occurs at altitudes between approximately 91 km (300 000 ft) and 168 km (550 000 ft) and between 500 and 550 sec following lift-off. The External Tank is released from the Orbiter approximately 30 sec after main engine cutoff. It breaks up and impacts downrange in a remote ocean area (the Indian Ocean for KSC launches and the South Pacific Ocean for VAFB launches). The two smaller OMS engines propel the Orbiter into orbit at the desired altitude. Figure 2-16 shows typical one-orbit mission trajectories for launches from VAFB and KSC.

Following the completion of orbital operations, the Orbiter is oriented to a tail-first attitude. After the OMS provides the deceleration thrust necessary for deorbiting, the Orbiter is reoriented nose-forward to the proper attitude for entry. The orientation of the Orbiter is established and maintained by the RCS down to the attitude where the atmospheric density is sufficient for the pitch and roll aerodynamic control surfaces to be effective (about 76-km or 250 000-ft altitude and 7900-m/sec or 26 000-ft/sec velocity). The yaw of the RCS remains active until the vehicle reaches an angle of attack of about 10 degrees (about 24-km or 80 000-ft altitude).

The Orbiter's entry trajectory provides lateral flight range to the landing site and energy management for an unpowered landing. The trajectory, lateral range, and heating are controlled through the attitude of the vehicle by angle of attack and bank angle.

During the final phases of descent, flightpath control is maintained by using the aerodynamic surfaces. Terminal area energy management techniques are initiated to provide the proper vehicle approach to the runway with respect to position, energy, and heading. Final touchdown occurs at an angle of attack of about 16 degrees. The maximum landing speed for 14 500-kg (32 000-lb) payload, including dispersions for hot-day effects and tailwinds, is about 207 knots.

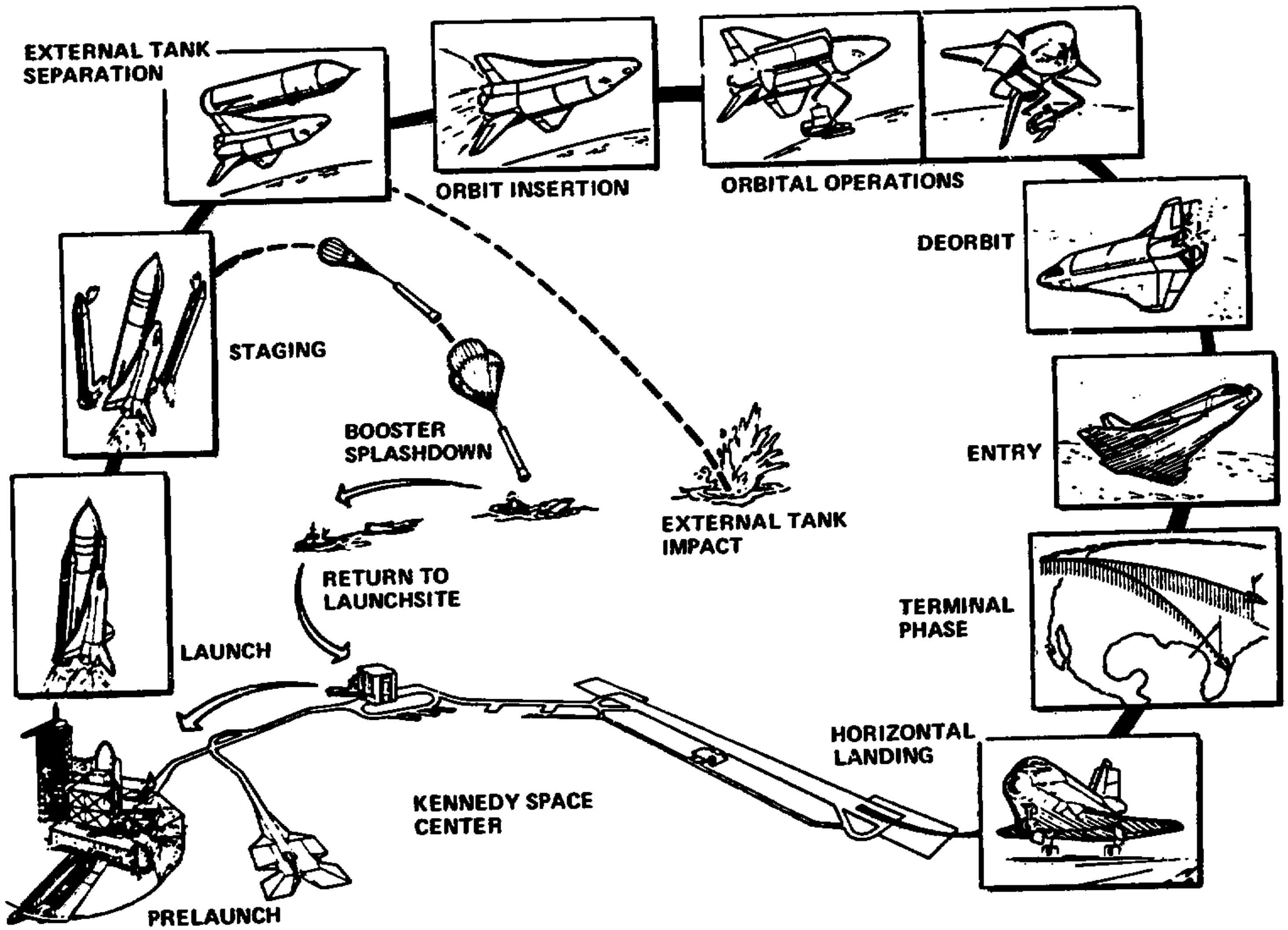


Figure 2-15.-- Typical profile of a Space Shuttle mission.

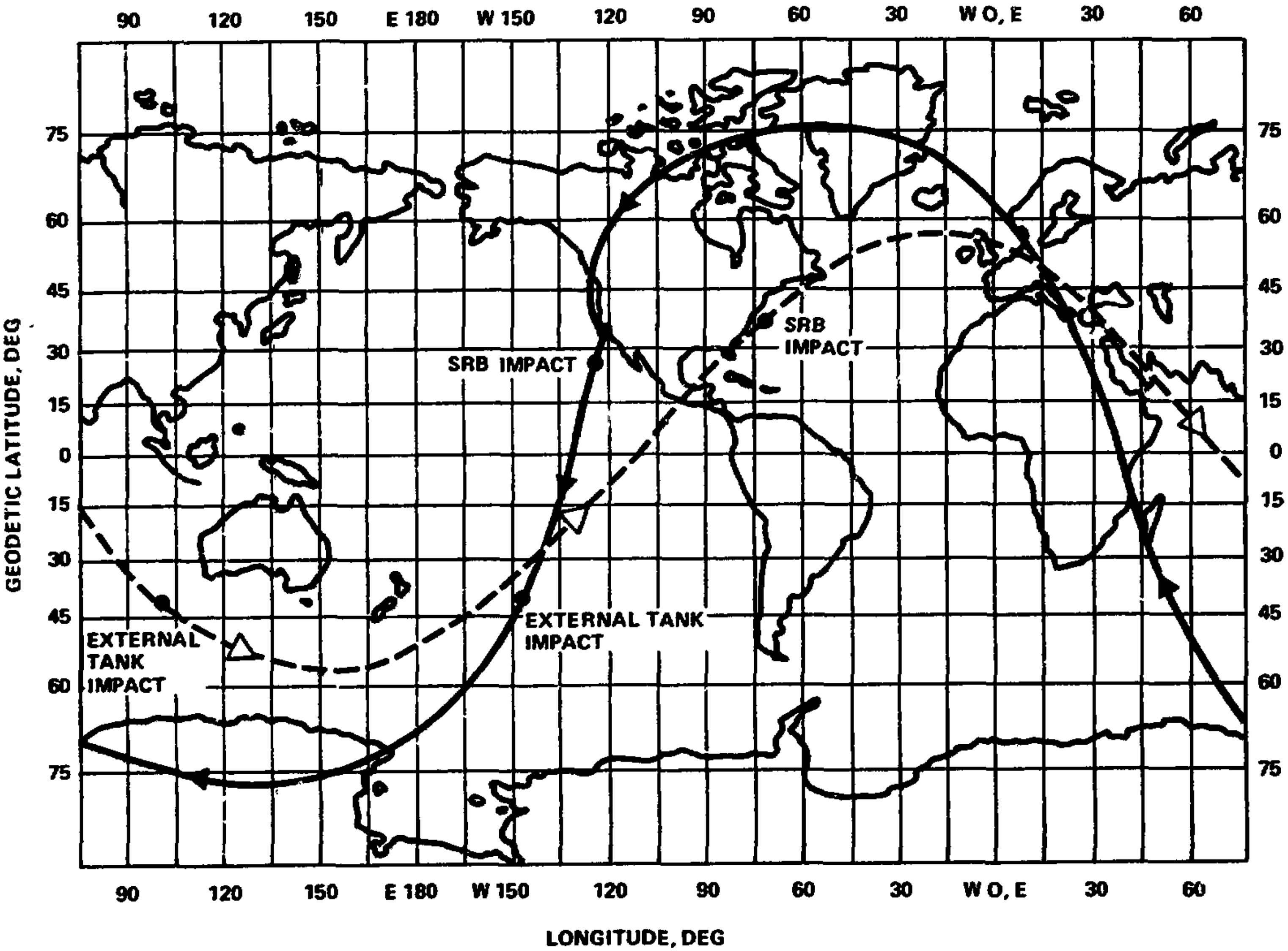


Figure 2-16.-- Typical one-orbit mission trajectories for launches from Vandenberg Air Force Base and Kennedy Space Center.

Contingency plans to deal with operational emergencies have been formulated. If one of the Space Shuttle's main engines fails during the early part of ascent, a return to launchsite abort will occur. This involves utilization of the OMS engines to provide required thrust, jettison of solid boosters, in-plane turn with the remaining main engines firing, release of External Tank when empty, and landing of the Orbiter at the launchsite. If a main engine failure occurs during in late part of ascent, the Orbiter will either continue to fly around the Earth on a suborbital trajectory and land at the launchsite after one revolution of the Earth; or it will continue into orbit, depending on when the main engine failure occurs.

Alternate airfields will provide landing opportunities for the Orbiter if, during abort situations or unfavorable weather conditions, the primary landing sites cannot be used. DFRC/EAFB has been designed as the secondary landing site for the Orbiter.

If the Orbiter cannot safely return to the launch and landing site, a contingency landing site will be used. Principal contingency airfields under consideration are Hickam Air Force Base, Hawaii; and Anderson Air Force Base, Guam. Negotiations with other U.S. owned and operated airfields around the world will be finalized during 1978.

2.3.2.3 Space Shuttle Missions for the 1980's

The Space Shuttle has been designed to support a wide variety of space missions (see fig. 2-17). The Space Shuttle and associated systems can satisfy all present launch vehicle requirements and can support new missions and operations, making possible the achievement of higher productivity for the space program and facilitating greater utilization of space resources.

The carrying of a single payload into orbit will not always utilize the full capability of the Space Shuttle vehicle. Payload bay volume permitting, excess capability can be used to advantage by adding payloads to the cargo manifest, allowing flight costs (of approximately $20 M) to be shared. Pooling of payloads can provide economic advantages when mission and schedule constraints are compatible. Studies of the prospects for mixing payloads show that the payloads of different agencies (NASA, DOD, other U.S. government agencies, commercial organizations, and international agencies) can be combined into efficient cargoes for Space Shuttle flights.

In addition to its ability to provide more cost-effective launch services, the Space Shuttle has been designed to service and refurbish low-Earth-orbit satellites; retrieve and return to Earth payloads weighing up to 14 500 kg (32 000 lb); perform dedicated experimentation and technology development missions; carry passengers in relative comfort; and, with suitable upper stage propulsion (e.g., interim upper stage and solid spinning upper stage), launch from orbit satellites and spacecraft whose missions require the attainment of high-orbital and Earth escape velocities. These capabilities can be used in many ways, some of which are

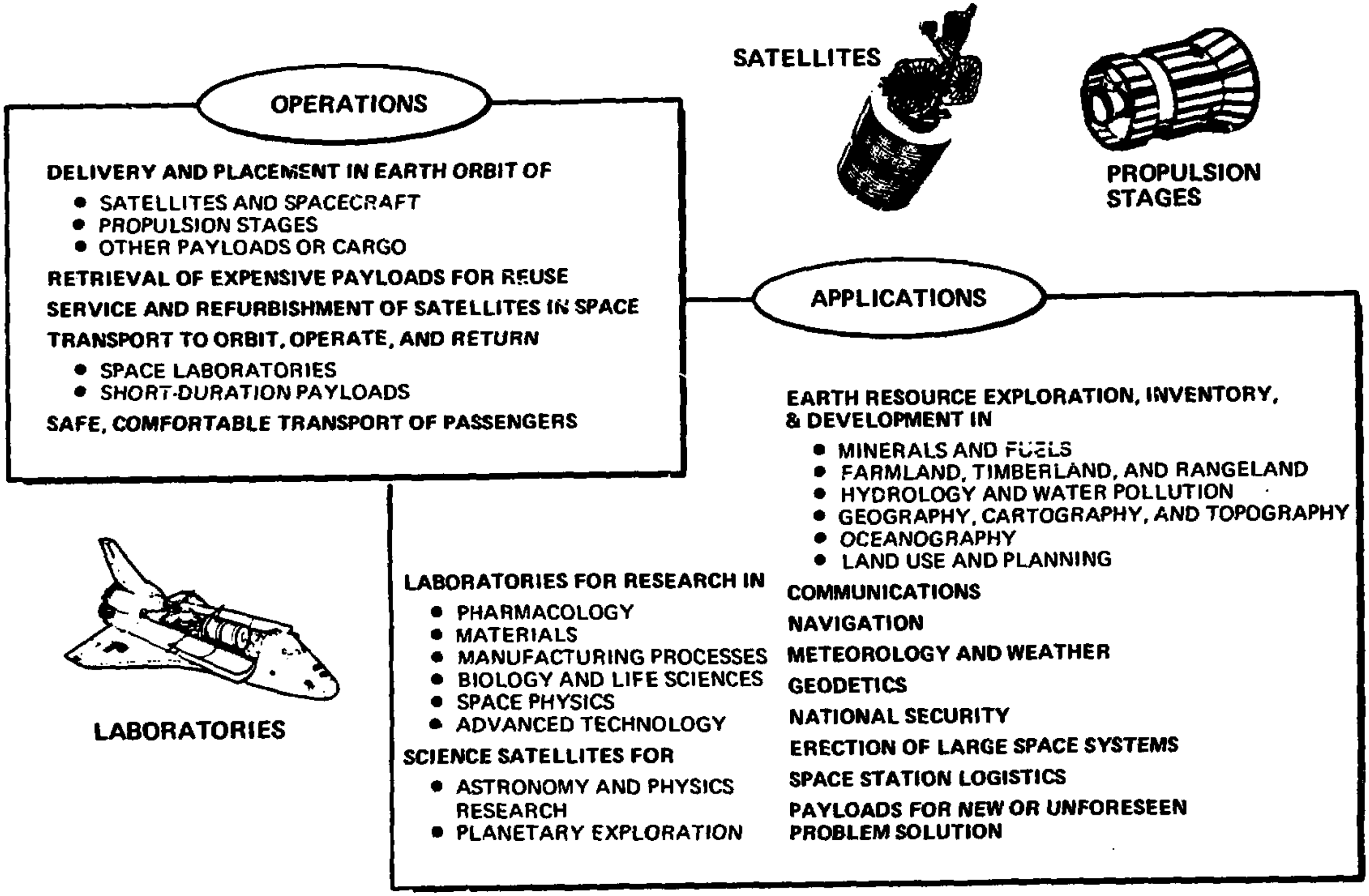


Figure 2-17.-- Summary of types of Space Shuttle missions.

listed in figure 2-17 as applications. Some of these applications have already evolved into vital programs (e.g., communications and weather satellites). Others await the special operational capabilities of the Space Shuttle to enable their initiation.

In addition to the Space Shuttle, other complementary space mission hardware systems are being developed and will be available as part of the 1980's STS. One of these systems is the Spacelab being developed under an international agreement by the European Space Agency (ESA). Spacelab will consist of pressurized, habitable modules and external experiment mounts or pallets which can be installed in various configurations in the Orbiter's payload bay.

Table 2-2 is a projection of Space Shuttle mission traffic in the 1979-1991 time period required to carry out all these types of missions (fig. 2-17), as foreseen in 1976. It should be noted that the projection periodically changes as new mission plans and revisions come into being.

As shown in table 2-2, the Space Shuttle launch rate is expected to build up from 3 in 1979 to approximately 60 per year beginning around 1984. Of the 60 launches, 40 are expected to be launched from KSC and the remaining 20 from VAFB. Some configuration of the Spacelab will be used in 40 percent of all missions, but 34 percent will require an interim or Space Shuttle upper stage. Space missions launched on Space Shuttle will be sponsored by NASA, DOD, NOAA, and various other space users, including private corporations and foreign governments.

2.3.2.4 Space Shuttle Vehicle Hardware Production and Transportation

Extensive production and transportation will be required to support mission models for which launch rates approach 60 per year. The following paragraphs discuss the hardware production and transportation activities that are significant to the program.

During the Space Shuttle's development phase, Orbiters 101 and 102 will be built. The Orbiter-101, named the Enterprise, will be used for testing; and the Orbiter-102 will be used for the orbital flight test program beginning in 1979. The Orbiter-101 has completed the approach and landing test at EAFB and is now at MSFC for use in full-scale vibration testing. Orbiter-101 will be used for the development flight test program and early operational flights. The third and fourth flight vehicles (Orbiters 103 abd 104) will be available for operational flight in mid-1983 and 1984, respectively.

The transportation of the Orbiter vehicles from Palmdale to KSC and VAFB will be accomplished by first transporting the Orbiter overland to DFRC and then mating it to the Boeing 747 carrier aircraft (see fig. 2-11) designed for ferrying the orbiters to the respective launchsite.

TABLE 2-2.-- SPACE SHUTTLE TRAFFIC PROJECTIONS

TABLE 2-2.-- SPACE SHUTTLE TRAFFIC PROJECTIONS

Mission	Calendar year, 19--													Total	Peak
	79	80	81	82	83	84	85	86	87	88	89	90	91		
Space Shuttle DDT&E	3	3												6	
Space Shuttle operations		5	15	24	48	60	60	60	60	60	60	60	60	572	60
Spacelab operations[a]		2	6	12	17	19	21	21	24	24	24	27	29	226	29
Interim upper stage operations[a]		3	8	12	15	17	22	21	21	20	19	20	19	197	22
Space Shuttle only		0	1	0	16	24	17	18	15	16	17	13	12	149	24
Space Shuttle KSC:															
NASA and other civil	[b]3	[b]5	10	18	31	33	32	33	33	34	33	32	32	329	34
DOD		3	5	5	5	7	8	7	7	6	7	8	8	76	8
KSC total	3	8	15	23	36	40	40	40	40	40	40	40	40	405	40
Space Shuttle VAFB:															
NASA and other civil				1	4	11	11	11	11	11	11	11	11	93	11
DOD					8	9	9	9	9	9	9	9	9	80	9
VAFB total				1	12	20	20	20	20	20	20	20	20	173	20
30-day missions[c]					2	2	2	3	4	6	5	6	6	36	6

[a]These operations include initial qualification (development) flights.

[b]These are development flights (three of five flights in 1980 are development flights).

[c]Of the 226 Spacelab flights, 36 are assumed to be 30-day missions, 2 from VAFB and 34 from KSC.

SRB hardware production and transportation activities in support of the first six Space Shuttle flights were discussed in section 2.3.1.2. For the SRM, NASA/MSFC has currently contracted Thiokol Corporation to supply SRM's for these test flights. For SRM separation motors, NASA/MSFC has currently contracted with CSD/UTC to produce the required motors. It is not yet established which contractors will be selected to manufacture SRM's or SRM separation motors to support the Space Shuttle operational program. The same is true for other SRB subsystems. Production and transportation of the SRB's for the operational program would be of the same character as for those of the first six flights.

For the SRM, the processing rate could grow to 120 SRM's per year (60 Space Shuttle flights per year). Approximately 70 individual SRM cases would be required, based upon 20 uses of each SRM case. The SRM contractor would subcontract for the new cases as required, load the SRM casting segments (four per motor) with solid propellant, refurbish or procure other SRM hardware, and ship SRM segments to the launchsites by rail. It is estimated that no more than 3600 kg (8000 lb) of waste propellant will be created for processing each SRM. To process 120 SRM's per year, the SRM contractor will have to dispose of about 430 000 kg (960 000 lb) of waste propellant per year (ref. 1-6).

The rail transportation rate for SRM casting segments during the development flights is 48 segments per year. For 60 Space Shuttle launches per year, assuming 40 at KSC and 20 at VAFB, 320 SRM segments per year would be transported to KSC and 160 to VAFB.

The SRB separation motor production rate to support a 60-per-year Space Shuttle launch rate would be 960 motors per year (16 motors per Space Shuttle flight). Current estimates indicate that less than 300 kg (600 lb) of waste propellant would be disposed of annually in processing plant burn pits. Motors would be transported via rail or truck to the two launchsites to support Space Shuttle operational flights.

External Tank production and transport during the development phase of the Space Shuttle Program were discussed in section 2.3.1.3. The production and transport of the External Tank to support 60 Space Shuttle flights per year are expected to be essentially the same as discussed previously, except for the increased rates. Tanks would be produced at the MAF and transported to either KSC or VAFB.

The MAF tooling currently in place can support an External Tank production rate of 20 to 24 per year; however, as production rate increases to 60 per year in the mid-1980's, additional tooling will be required.

Currently, two barges, each barge capable of carrying one External Tank, are available to transport External Tanks to the launchsites at either the East or West Coast. Two additional barges, with modifications, could also be used. A new barge that can hold four External Tanks for transport during the early years of the Space Shuttle Program is currently being considered. Production of 60 tanks per year will eventually require a larger barge fleet.

2.3.2.5 Propellant Production and Transportation

Various types and quantities of liquid and solid propellants will be required to support the flight operations phase of the Space Shuttle Program (see section 8.1.1 for more detailed information). Liquid propellants will be delivered to the respective launchsites. Solid propellant ingredients will be delivered to the SRM processor, who will then prepare and place the solid propellant into the motor segments prior to rail shipment to the launchsites. Table 2-3 lists the propellants and the mode of transportation.

The liquid propellants used by the Space Shuttle include liquid hydrogen, liquid oxygen, MMH, hydrazine, and nitrogen tetroxide. Table 2-3 lists the names of the current contractors for these propellants, gives their locations, provides a projection of usage, and indicates the mode of transportation.

The solid propellant ingredients used in the Space Shuttle SRM and SRB separation motors include ammonium perchlorate powder, aluminum powder, PBAN binder, hydroxy-terminated polybutadiene (HTPB) binder, and iron oxide. Table 2-4 lists the names of the current contractors for these propellants, gives their locations, provides a projection of usage, and indicates the mode of transportation to the SRM and separation motor contractor processing plants. After the propellants are processed (mixed, cured, and finished), the motors containing the solid propellant will be transported, via rail (SRM) and truck (separation motor), to the specific launchsites.

2.4 Existing Environments

Detailed descriptions of the existing environments of facilities at which major Space Shuttle activities will occur have been presented in the individual environmental impact statements prepared for Space Shuttle activities at that location (see refs. 1-2 to 1-9). The purpose of this section is to present a brief review of the general environment of each location.

Figure 2-7 indicates the locations of these facilities throughout the United States. The five geographical areas where a significant amount of Space Shuttle Program activity is expected to occur are also listed in table 2-5. The following paragraphs briefly discuss the existing environments of each of these geographical areas.

2.4.1 Southern California

Construction and assembly of the Orbiter will take place at USAF Plant 42 in Palmdale, California. The Orbiter will be transported overland along a fixed route (56 km, or 35 miles) to DFRC. At DFRC, the Orbiter will be mated to a Boeing 747 for ALT's or delivery to launchsites. Additionally, the dry lakebed runway will serve as the landing site for the first four flights during the Space Shuttle orbital flight

TABLE 2-3.-- MAJOR LIQUID PROPELLANT/PRESSURANT/FLUID PRODUCTION REQUIREMENTS AND MODE OF TRANSPORT

Liquid propellant pressurant/fluid	Current producer and location[a]	Projected peak annual requirement,[b] metric tons			Transportation
		KSC	VAFB	Total	
Liquid hydrogen	Air Products & Chemicals, Inc. New Orleans, La.	7 090	3 630	10 720	Mobile tankers, barge, or railcar
Liquid oxygen	Linde Chemical Co. Mims, Fla.	46 400	25 000	71 400	Mobile tanker truck
MMH	Olin Chemical Co. New Orleans, La.	218	111	329	Railcar and mobile tanker
Hydrazine	Olin Chemical Co. New Orleans, La.	27	13.5	40.5	Railcar and truck
Nitrogen tetroxide	Hercules Co. Bell, Calif.	320	163	483	Railcar and mobile tanker
Nitrogen gas	Big Three Corp. Merritt Island, Fla.	35 720	31 470	67 190	Pipeline and truck
Liquid nitrogen	Linde Chemical Co. Mims, Fla.	5 440	3 630	9 070	Mobile tanker
Helium gas	U.S. Government Amarillo, Tex.	258	145	404	Railcar and pipeline
Freon-113	DuPont Chemical Co. Allentown, Pa.	1 317	908	2 225	Railcar and mobile tanker
Isopropyl alcohol	Various suppliers	726	366	1 092	Railcar and mobile tanker
Water	Launchsite-produced	31 720	19 600	51 380	Pipeline railcar, mobile tanker, and flat-bed truck

[a]Current contractors may change as a result of competitive procurement actions of the future.

[b]This projection is based on 40 Space Shuttle launches per year from KSC and 20 per year from VAFB.

TABLE 2-4.-- SOLID PROPELLANT INGREDIENT REQUIREMENTS AND MODE OF TRANSPORT

Solid propellant ingredient	Current producer/location[a]	Projected peak annual requirement,[b] metric tons			Transportation mode
		SRM	Separation motor	Total	
Ammonium perchlorate	Kerr-McGee Henderson, Nev.	42 400	24	42 424	Railcar and trailer truck
	Pacific Engineering Henderson, Nev.				
Aluminum powder	Alcoa Rockdale, Tex.	9 745	.6	9 745.6	Railcar and trailer truck
	ALCAN Berkeley, Calif.				
PBAN binder	American Synthetic (PBAN) Louisville, Ken.	8 529	--	8 529	Railcar and mobile tanker
	Dow Chemical (epoxy curing agent) Freeport, Tex.				
HTPB binder (separation motor only)	Arco Los Angeles, Calif.	--	4.0	4.0	Trailer truck
Iron oxide	Charles Pfizer Co. Easton, Pa.	244	--	244	Trailer truck

[a]Current contractors may change as a result of competitive procurement actions of the future.

[b]This projection is based on 120 SRM's per year and 960 separation motors per year.

TABLE 2-5.-- GEOGRAPHICAL AREAS SUPPORTING MAJOR SPACE SHUTTLE PROGRAM ACTIVITY

Geographical area	Location	Space Shuttle program activity
Southern California	Rockwell, Santa Susana Rockwell, Downey (near Los Angeles) Rockwell, Palmdale NASA/DFRC Others	Main engine test firing Orbiter subassembly Orbiter final assembly Orbiter horizontal flight test Various manufacturing
Utah	Thiokol/Wasatch, Promontory	SRM DDT&E program: SRM processing SRM test firings
Mississippi/Louisiana	NASA/MAF, New Orleans NASA/NSTL, Bay St. Louis	External tank production and testing Main engine test firing
Florida	NASA/KSC, Cape Canaveral	Flight operations
California	DOD/VAFB, Lompoc	Flight operations

operations phase and thereafter will be designated as an alternate runway. More details on the environment of this area are presented in reference 1-3.

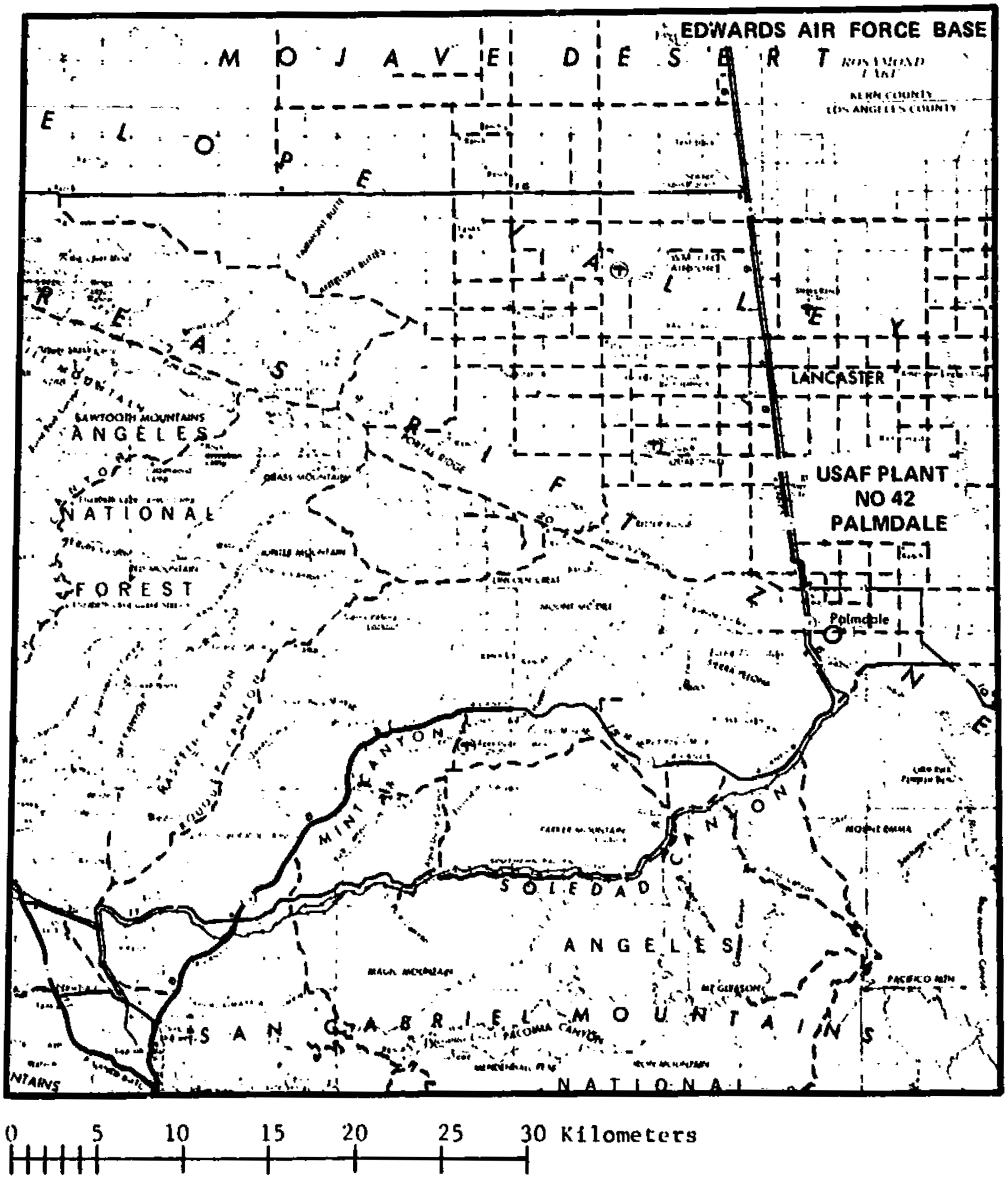
The route of the overland transport of the Orbiter from Palmdale to the DFRC occurs within the Antelope Valley over properties under the jurisdiction of the USAF and Los Angeles County; see figures 2-10 and 2-18 (a). The general area along the route is sparsely populated, rolling, dry desert with mountain ranges in the distance. The terrain along the route is fairly level with a general downward slope to the north.

The Antelope Valley has been filled with a wide range of alluvial sediments derived from the mountains to the south and west. These sediments are variable but because of the high percentage of coarsegrained materials, are generally considered moderately to highly permeable. The material in Rogers Lake at the site of the runway (northern end of the proposed route) consists predominantly of clay. USAF Plant 42 (Orbiter assembly plant at the southern end of the route) is located 8 km (5 miles) northeast of the San Andreas Fault trace near the location of the recently identified "Palmdale Bulge." The Garlock Fault trace is located 32 km (20 miles) northwest of DFRC.

The climate of Antelope Valley is arid. Summers are characteristically hot; winters are mild to cold. Prevailing surface winds are generally light and flow from the southwest to west-southwest. Visibility is more than 16 km (10 miles) 96 percent of the time. Precipitation is almost always in the form of rainfall, which averages 16.8 cm (6.6 in.) annually, 90 percent of which occurs from November through April.

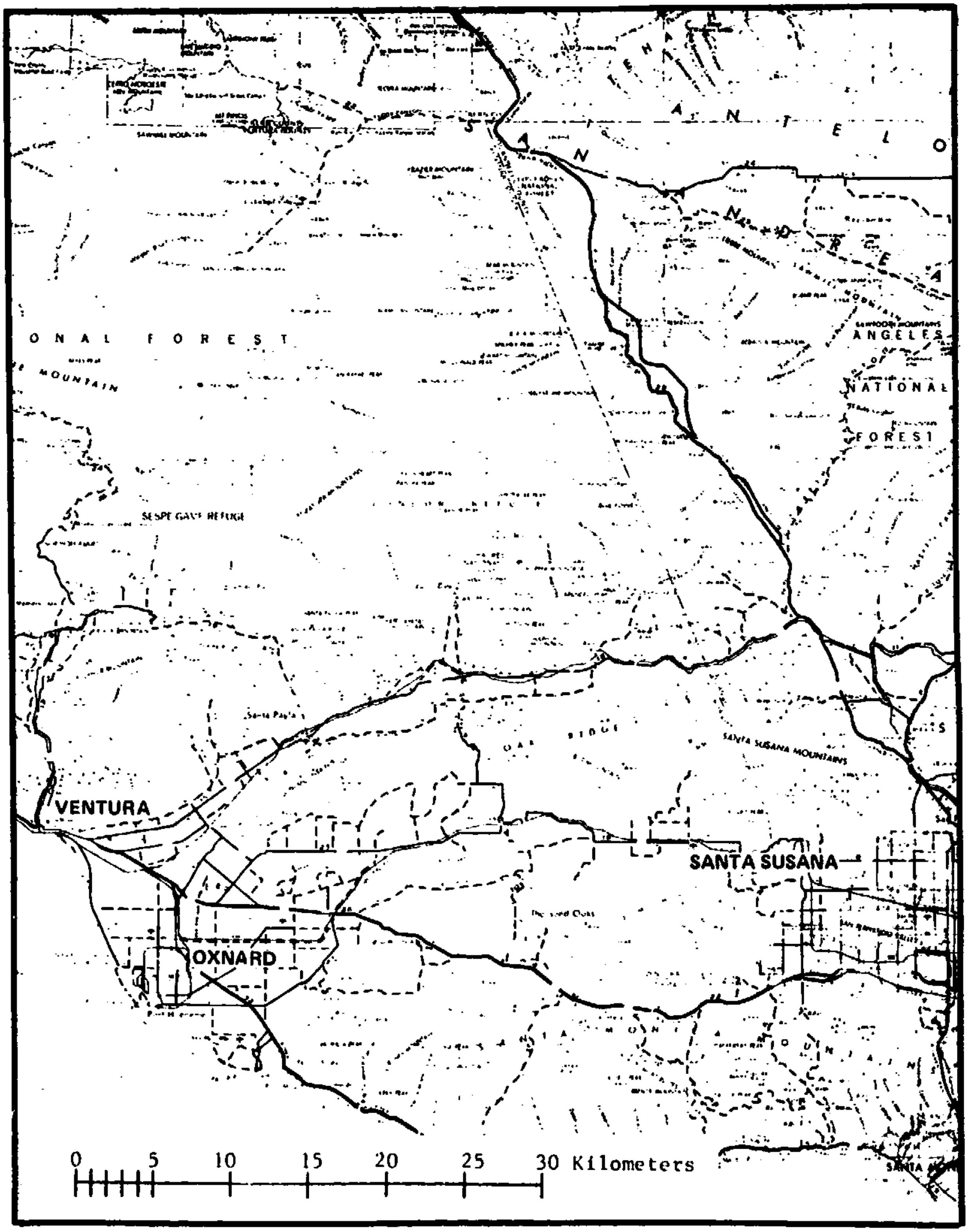
The biological communities occupying the area are typical of Mohave Desert communities on well-drained alluvium below an elevation of 1525 m (5000 ft). This type of habitat is common in northeast portions of Los Angeles County. Major plant species include buckthorn (Ceanothus sp.), sage (Salvia sp.), creosotebush (Larrea tridentata), and Joshua tree (Yucca brevifolia). Alfalfa is the principal crop on the limited cultivated land. Species represented are those typical of desert shrub and dry-wash (seasonal drainage) habitats. It should be noted that the California condor, an endangered species, is observed to feed in this area perhaps two or three times a year during the months of October and November. The prairie falcon, a threatened species, is also known in this area.

Rockwell will conduct static tests of the main engine of the Space Shuttle at the Santa Susana Field Laboratory, USAF Plant 57, in Santa Susana, California; see figure 2-18 (b). This laboratory is located at the west end of the San Fernando Valley in Ventura County, California. The area located within a radius of 16 km (10 miles) of the test site is considered to be the zone in which rocket noise might be discernible. This area contains 13 communities (i.e., locations with specific names) with a population of approximately 400 000. The physical and biological environment is described in reference 1-2 and is similar to that for VAFB (ref. 1-9).



(a) Edwards Air Force Base/Palmdale.

Figure 2-18.-- Local features of area surrounding Space Shuttle Program activities in southern California.



(b) Santa Susana Test Facility.

Figure 2-18.-- Concluded.

2.4.2 Promontory, Utah

The facilities of the Wasatch Division of Thiokol Corporation are located in the eastern half of Box Elder County near Promontory, Utah. This site will be the location of SRM processing and test firings during the development phase of the Space Shuttle Program (see ref. 1-5). The 77-km^2 (30-mi^2) plantsite is remote from any major population center.

Lying at the northern end of the Great Salt Lake, Thiokol/Wasatch is within the basin and range physiographic province (see fig. 2-19). Topographically, the site is a series of relatively low, rounded mountains that extend from north to south, separated by broad intervening valleys. Isolated peaks of the Wasatch Range east of Thiokol rise from 2750 to 3050 m (9000 to 10 000 ft). The Promontory Mountains west of Thiokol rise to a maximum of 980 m (3200 ft) above lake level. Thrust and fault block mountains of metamorphic rocks separated by various sedimentary materials typify the surficial geology. Soils are extremely well drained except for the marshlike soils along Blue Spring Creek, the only first-order stream on the Thiokol/Wasatch plantsite.

Surface waters are largely the result of snowmelt and are therefore seasonal. The quality of the water is rather poor because of naturally high dissolved solids. Ground-water hydrology of the area is complex. There are numerous springs, most of them saline and artesian. There are, however, several fresh-water and several "hot" springs.

The climate of the Great Salt Lake basin is largely dominated by the Sierra Nevada to the west and the Rocky Mountains to the east, which exert a moderating influence. Monthly mean temperatures range from 2° C (28° F) in January to 25° C (77° F) in July (ref. 2-3). The mountains contribute significantly to the arid nature of the basin with an average annual precipitation of approximately 30 cm (12 in.). During the year, it is expected that 35 percent of the days would be clear, 30 percent would be partly cloudy, 34 percent would be cloudy, and approximately 1 percent would be foggy.

The ecological component of the Thiokol plantsite is upland habitat with the following exceptions: developed areas occupying 25 percent of the site and wetland habitats along Blue Spring Creek. The dominant vegetation type is a shrub complex of bluebunch wheatgrass (Agropyron spicatum) and shadscale (Atriplex sp.). No threatened or endangered species are known to inhabit or frequent the Thiokol/Wasatch plantsite.

The delta of the Bear River, located 18 km (11 miles) southeast of Thiokol/Wasatch, is the site of the 260-km^2 (100-mi^2) Bear River Migratory Bird Refuge administered by the U.S. Fish and Wildlife Service (ref. 2-4). The Bear River delta occupies an important position on both the Pacific and central migratory flyways and is utilized by millions of waterfowl and shorebirds during spring and fall nesting. The peregrine falcon, an endangered species, makes extensive seasonal use of the Bear River Migratory Bird Refuge.

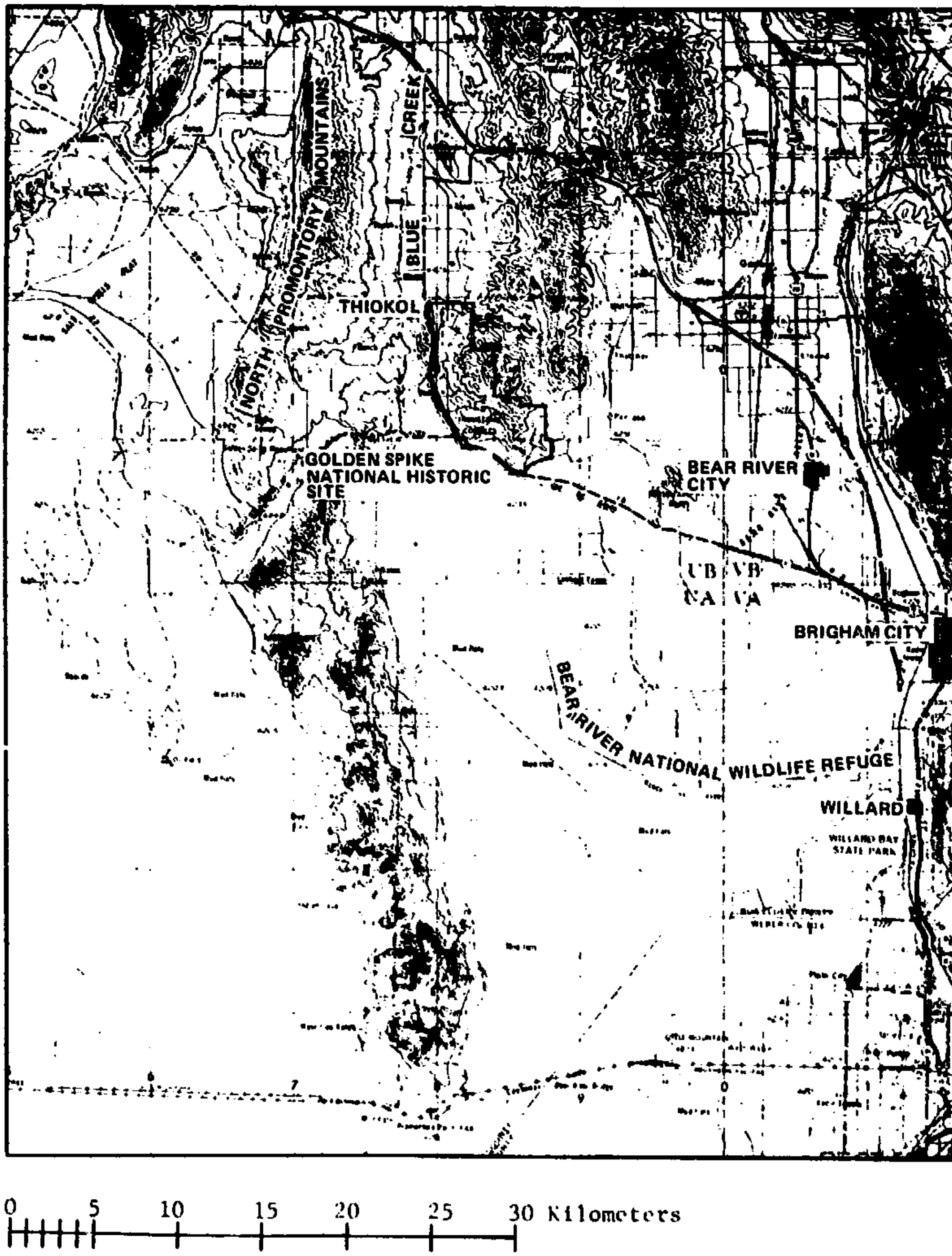


Figure 2-19.-- Local features of the area surrounding the Thiokol/Wasatch plantsite near Promontory, Utah.

Brigham City (with a population of 14 000) is the county seat of Box Elder County (population of 31 000). Located 32 km (20 miles) from the plantsite, it is the home of approximately 1000 of Thiokol's 2400 employees. Family groups living in the area of the Thiokol/Wasatch facility can be classified into two general groups: ranchers and/or dry farmers and externally employed heads of households who commute long distances. Services and facilities of the region are widely spaced, except with the population center of Brigham City. No schools, hospitals, churches, or other centers of community activity are located near the Thiokol facility.

Thiokol/Wasatch Division is the largest Utah employer north of the Ogden metropolitan area and is one of the 15 largest employers in the state. Historically, employment patterns at Thiokol have been relatively constant, reaching a peak during maximum production of the Minuteman missile at that facility. The employment situation in Box Elder County can be generally described at the present time as "substantial unemployment." Great Salt Lake serves as the focus for recreational activities of residents and many visitors in the summer season. The Golden Spike National Historic Site located 10 km (6 miles) from Thiokol at Promontory attracts approximately 55 000 visitors each year. Winter recreation is focused at ski resorts in the Wasatch Range.

2.4.3 Mississippi and Louisiana

Two areas of significant Space Shuttle activity occur within the region indicated in figure 2-20: the MAF near New Orleans, Louisiana; and the NSTL, northwest of Bay St. Louis, Mississippi. Production and testing of the External Tank during the development and flight operations phases of the Space Shuttle will occur at the MAF (ref. 1-8). The NSTL will be the location of static test firings of the Space Shuttle's main engine (ref. 1-4).

Both facilities are located on river deltas, the MAF on the Mississippi River and the NSTL on the Pearl River. The areas are generally very flat, although the NSTL is located on a slight north/south elevated ridge east of the Pearl River Valley. Natural and manmade levees provide only slight elevational differences. Natural marshlands, swamps, and natural manmade waterways are common. Soils are very fine, ground water is typically very shallow, and depth to bedrock is typically great. Frictional pilings for support are traditional. The area occupied by buildings at the MAF is levee-protected, reclaimed marshland with surficial materials composed entirely of manmade fill, a mixture of topsoil and river sand.

Southeast Louisiana and southwest Mississippi have a humid subtropical climate modified by the Gulf of Mexico. Monthly mean temperatures range from 13.3° C (55.9° F) in January to 28.6° C (83.4° F) in August. Prevailing winds are seasonal. Precipitation is rather high, averaging above 150 cm (59 in.) annually. Maximum-intensity precipitation usually

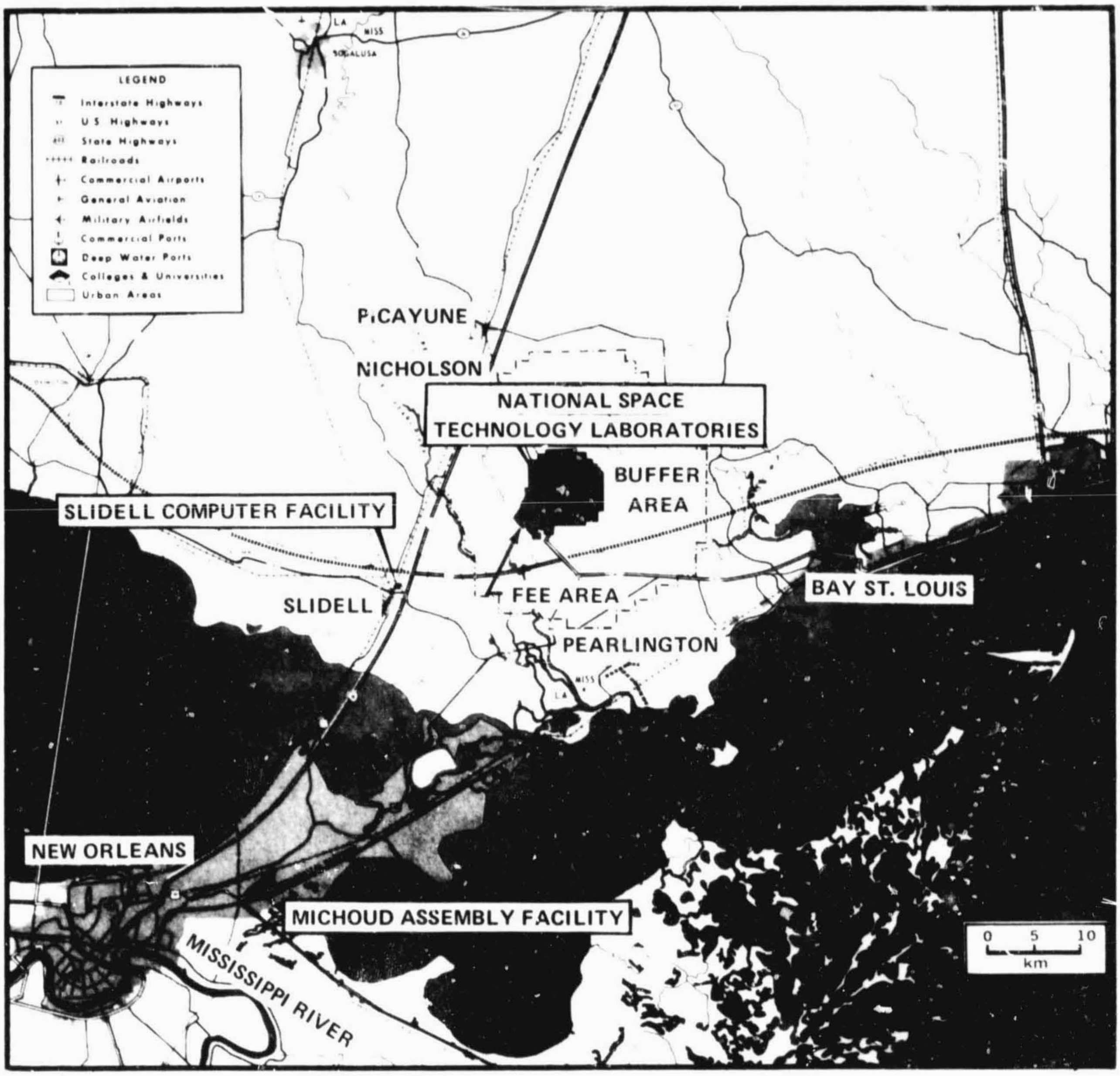


Figure 2-20.-- Local features of area surrounding Space Shuttle Program activities in Louisiana and Mississippi.

occurs in the summer during thunderstorms and tropical storms, although thunderstorms occur in all seasons and may be accompanied by high winds (ref. 2-5). The portion of Louisiana and adjacent Mississippi extending from Timbalier Bay eastward, but excluding the Mississippi River mouth, is likely to experience approximately 45 hurricanes in a 100-year period (ref. 2-5).

The biological environment of the MAF is composed of leveed, filled developed areas, adjacent to both high and moderate quality marshland and aquatic areas and to other developed areas. This is not unusual for any facility located on the perimeter of the New Orleans metropolitan area. The Intracoastal Waterway and Michoud Canal and adjacent marsh to the south and east are highly productive wetlands supporting both sizeable commercial fish and shellfish industries and large populations of non-commercial, natural organisms.

The natural habitat of the NSTL is predominantly slash/loblolly pine flats, with a few intermixed bald cypresses. This is supported on a sticky, saturated "gumbo" soil. To the west along the Pearl River, a vast deep hardwood swamp develops. This is the classic cypress-gum swamp forest. Hunting is prohibited on the 65-km^2 (25-mi^2) main area of the NSTL but may occur on a per-parcel basis on the larger, privately owned buffer areas. Deer, turkey, bobcat, and fox abound. The alligator (still listed as an endangered species in Mississippi) is thriving in the area. The Florida panther has been reported in the area. An excellent habitat for the red-cockaded woodpecker is available, though none have been sighted. The biota of the NSTL are unique in that many species exhibit intergrade characteristics of both eastern and western subspecies, particularly of reptiles, amphibians, and squirrels.

The MAF currently employs about 3800, including contractors, most of whom live within the greater New Orleans area. Employment at this facility has fluctuated widely and is currently down from an all time high of about 12 000 (in 1964). During the mid-1960's, manufacturing was the dominant activity at the MAF. However, white-collar workers now account for 75 percent of onsite employment. Most of these individuals commute from other New Orleans suburbs and therefore contribute more to the overall New Orleans socioeconomic patterns than to the immediate communities along Chef Menteur Highway (Route 90).

The small communities closest to the NSTL are Nicholson in the northwest, Pearlington in the south, and Kiln in the east. Their economies have not been as greatly affected by their proximity to the NSTL as have the economies of the larger, more distant communities, including Picayune, Bay St. Louis, and Waveland, Mississippi; and Slidell, Louisiana. Some of the major communities have increased their facilities by as much as 200 percent since the establishment of the NSTL in the mid-1960's. The NSTL occupies approximately 5260 hectares (13 000 acres) and is surrounded by a 50 600-hectare (125 000-acre) acoustical buffer zone inhabited only by livestock and wildlife, with some farming and lumbering permitted. Less than one-fifth of the central 5260-hectare (13 000-acre) area is developed. The NSTL site includes a 6-m (20-ft) lift lock to the Pearl River and 12 km (7.5 miles) of manmade canals in addition to the natural waterways.

2.4.4 Kennedy Space Center

KSC is located on approximately 57 000 hectares (140 000 acres) on Merritt Island in Brevard County, Florida, and adjoins the Cape Canaveral Air Force Station, as indicated in figure 2-21. The first Space Shuttle launch is currently scheduled to take place at KSC in 1979. The environmental effects are described in reference 1-5.

Average elevation of the land is from 3 to 4 m (9 to 14 ft) above mean sea level. The KSC area is part of the Gulf-Atlantic coastal flats. The site is situated on platform deposits overlying basement rock of the Paleozoic Age. There are no caverns or significant metal or mineral deposits in the area. There have been no earthquakes since October 1973. Soil on land around the island is either warm, moist cracking clay or warm, wet podsols; the island is sandy.

The Banana and Indian Rivers are shallow lagoons which lie to the east and west of Merritt Island, respectively. Average depths range from 1 to 1.5 m (3 to 4 ft), except for the channel of the Intracoastal Waterway, which is maintained at a depth of 3.7 m (12 ft).

The climate at KSC can be described as humid subtropical. Approximately 124 cm (49 in.) of rainfall is the annual average, with the rainfall fairly uniform throughout the year. Temperatures are warm throughout the year. The average winter temperature minimums are typically 13° C (55° F); and in the summer, temperature lows (ref. 2-6) are 23° C (74° F) and highs are 31° C (88° F). Thunderstorms are fairly common in the spring and summer (ref. 2-7). Severe storms are not common but may occasionally come from the northeast. Flooding may occur in low areas as a result of storms breaching the natural protective dunes.

KSC is subject to sea and land breeze phenomena. This condition prevails in the summer and occurs intermittently in spring and fall and infrequently in winter. When the sea/land breeze condition does not prevail, spring and summer seasons are characterized by southerly and easterly winds. During the fall, north and easterly winds occur most often; whereas in the winter, the predominant winds are north and northwesterly.

The higher ground of KSC is vegetated by a cover of palmetto shrubs, scattered sabal palms, and southern pine species. Other natural vegetation on Merritt Island includes live oak forest and southern mixed forest. Sea oats and other dune vegetation predominate along the Atlantic shoreline on the stabilized foreshores and dunes. Animal and bird species typical of these habitat types are present. Because of the protected nature of these lands, numbers of individuals are likely to be above habitat areas which are not similarly protected.

Citrus fruit production is the predominant agricultural practice in the area. There are several groves within KSC that are leased to private individuals. A symbiotic activity of the citrus groves is a $1-million honey industry.

Under agreement with the U.S. Fish and Wildlife Service, the boundaries of the Merritt Island Wildlife Refuge and KSC are coextensive. This

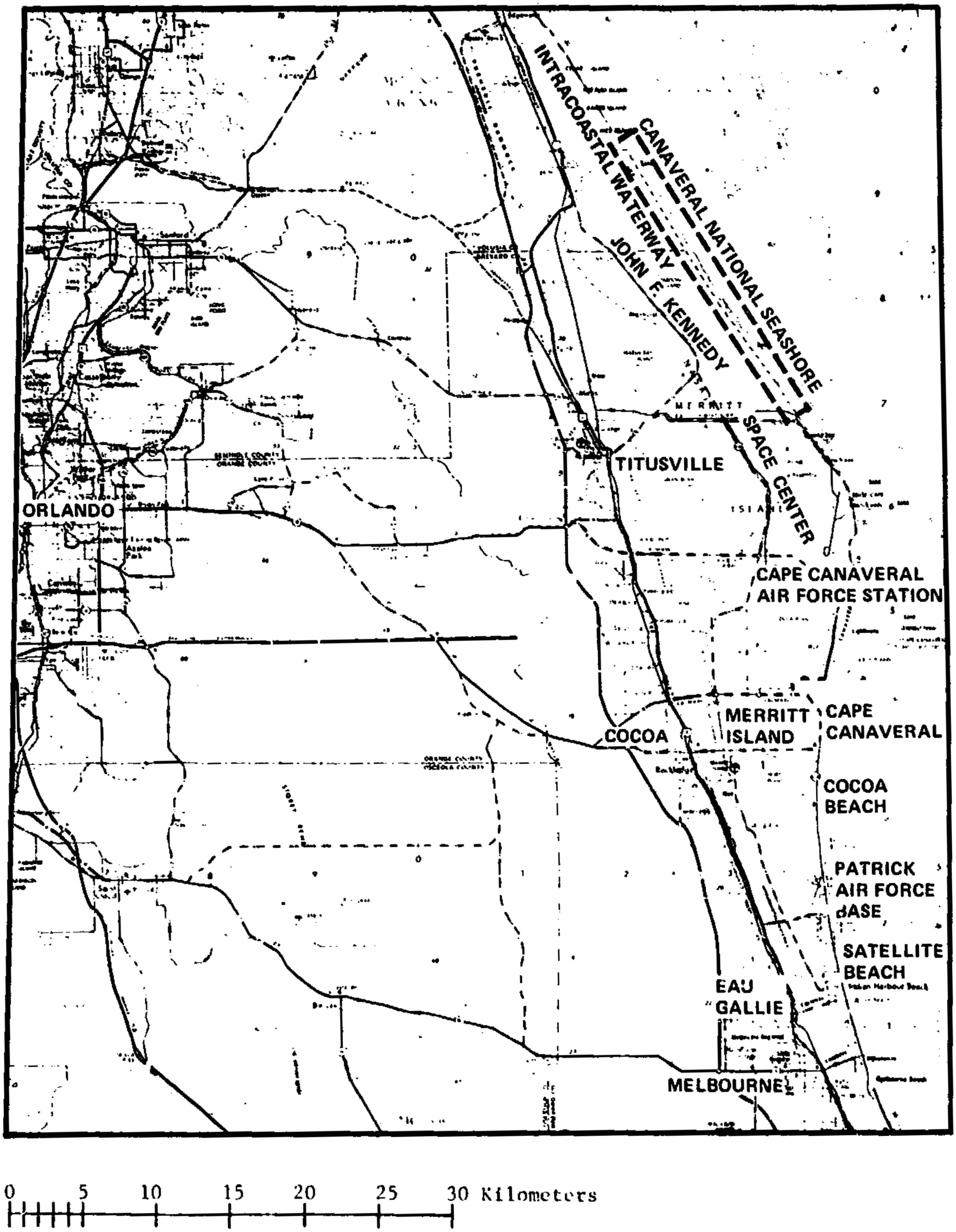


Figure 2-21.-- Local features of area surrounding Space Shuttle Program activities in Florida.

agreement[2] provides that the U.S. Fish and Wildlife Service, subject to enumerated conditions, shall have primary administration over all property not related to the space program. In addition, 16 592 hectares (41 000 acres) of KSC are encompassed in the Canaveral National Seashore (Public Law 93-626).[3] Of these 16 592 hectares, 2693 hectares (6655 acres) are part of the national seashore administered by the National Park Service; and 13 899 hectares (34 345 acres) are part of the Merritt Island National Wildlife Refuge.

Personnel supporting KSC reside principally in the communities of Titusville, Cocoa, Cocoa Beach, Satellite Beach, Melbourne, Merritt Island, and Orlando. The average rural density is estimated to be 32 persons per km^2 (84 per mi^2) for Brevard and its contiguous counties. Slightly less the one-half million persons live in urban communities within the contiguous area.

The original economy of the area was based on agriculture and tourism. The advent of the space program brought about rapid development in the area and was followed by an economic depression when the Apollo program ended. Since then, the local economy has adjusted through diversification to agriculture, tourism, retirement living, and various government programs.

2.4.5 Vandenberg Air Force Base

VAFB will be the second operational launchsite for the Space Shuttle (ref. 1-9). VAFB is located in Santa Barbara County, California, approximately 70 km (42 miles) northwest of Santa Barbara and 190 km (120 miles) north of Los Angeles (fig. 2-22).

The surface geology of the area surrounding VAFB reflects the existence of two geomorphic provinces (the southern coast ranges and the transverse ranges) and two stratigraphic provinces (the Santa Ynez Mountains and the Santa Maria Basin). Mountain building (orogenic) processes are still occurring in the region, as evidenced by the numerous fault zones and periodic earthquakes. Although VAFB is located in an area which historically has been subject to earthquakes, there has been no recorded damage to the base (ref. 2-8). Tsunamis associated with local and distant earthquakes have been reported at Point Hueneme and along the VAFB coastline.

Surface water runoff at VAFB is drained by two larger basins, San Antonio Creek and the Santa Ynez River. High discharge occurs from November through May, and very little or no discharge occurs in the drier months. Water supply is considered a major public issue in the Santa Barbara County area. The Santa Ynez River and smaller tributaries are subject to floods, particularly flashfloods during periods of excessive runoff.

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[2]NMI 1052.91A (February 2, 1972) as superseded by NMI 1052.188 (April 2, 1975).

[3]See 16 USC 459j et seq.

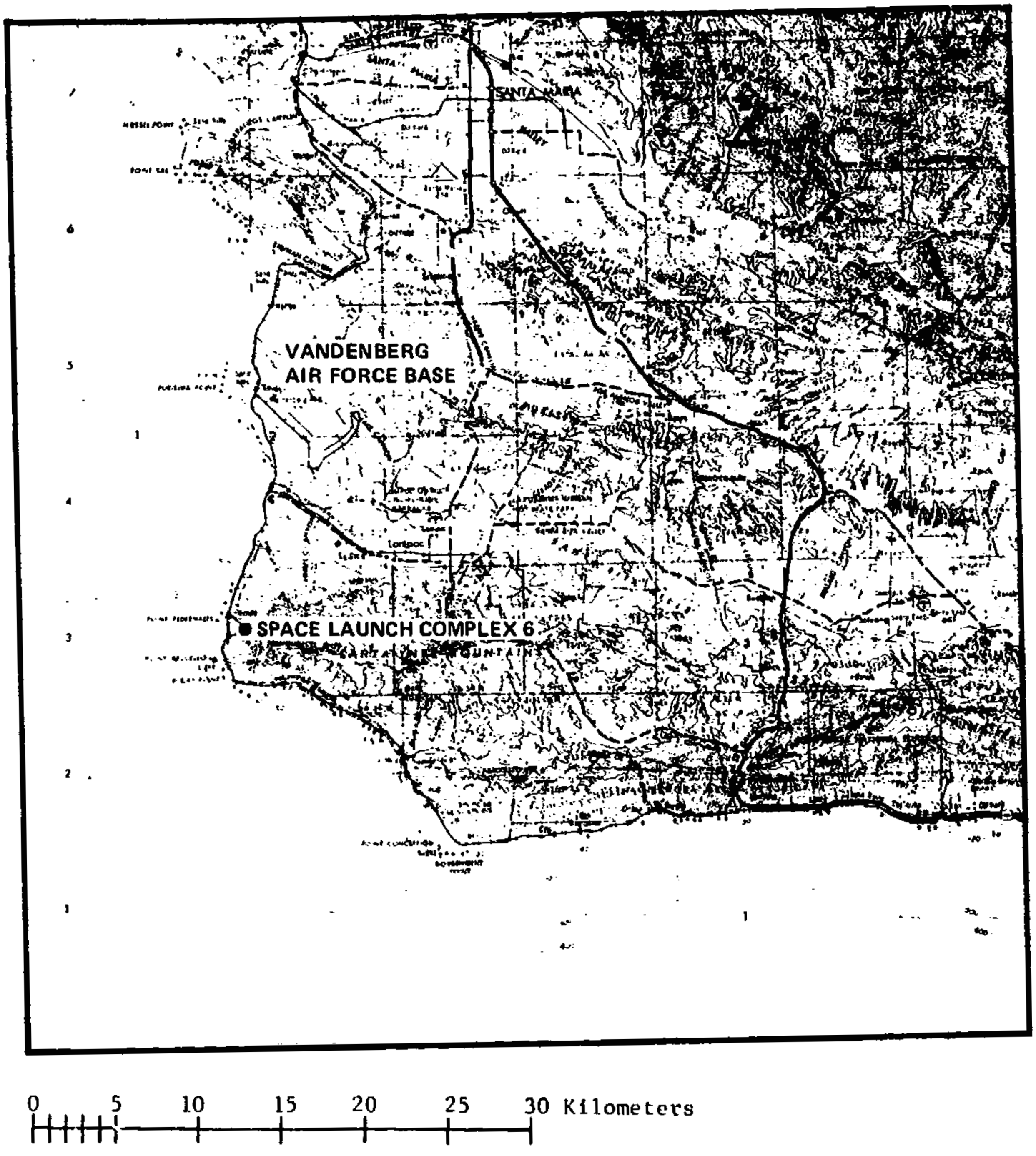

Figure 2-22.-- Local features of area surrounding Space Shuttle Program activities at Vandenberg Air Force Base.

The ground-water situation is very complex and varies greatly between the various formations. However, current estimates are that Santa Barbara is withdrawing ground water at a faster rate than recharge maintenance (ref. 2-9). Currently, 80 percent of Santa Barbara County's water resources is derived from ground water and 20 percent from surface resources (see ref. 2-9). Salt water intrusion is not currently a threat, though continued overdrafting may alter that situation.

The southern California climate along the coast is characterized by dry, subhumid, and semiarid zones. This climate provides warm to hot summers and unusually mild winters. Generally, there are abundant sunshine, few rainy days, and moderate to little seasonal variation. The most characteristic feature is the persistent night and morning low cloudiness and fog, followed by sunny afternoons. Daytime winds are generally brisk and westerly; whereas nighttime winds are often very rare. The total annual precipitation for the VAFB region is typically about 33 cm (13 in.), with the predominant amount occurring during the winter months.

The terrestrial vegetation of VAFB is highly variable with respect to distance from the ocean, altitude, and aspect. Most areas of VAFB where Space Shuttle activities are planned have already been developed into buildings or managed grasslands. The existing launch complex (Space Launch Complex 6), which will be modified for Space Shuttle launches, is centered on a plateau above the ocean and is surrounded by a coastal sage scrub habitat that is currently being grazed by domestic cattle. Animals are abundant in this habitat type. Principal species include California valley quail and three rabbit species. Mule deer and feral pigs are the major large mammals. Several threatened and endangered terrestrial and marine species are known in this area.

Based on political, physical, social, and economic criteria, VAFB is divided into two zones -- the southern and central portions of the base, which are adjacent to the Lompoc Valley area; and the northern boundary of the base, which leads to the Santa Maria Valley. These two areas form the northern and eastern boundaries, and the Pacific Ocean forms the western and southern boundaries of VAFB. Approximately 60 percent of the VAFB working population lives in the Lompoc Valley, which provides a full range of economic services. The Lompoc Valley is an important area for commercial flowerseed production for the United States. Approximately 150 species of flowers are grown for seed on about 970 hectares (2400 acres). More than 35 percent of the VAFB employees living offbase reside in the Santa Maria Valley; almost all of these reside in either Orcutt or Santa Maria.

Los Angeles County is the major source of goods and services, particularly transportation and manufacturing, for all of the southern California region, including VAFB. Goods and services not economically available from local vendors are provided to VAFB from the Los Angeles area.

3. RELATIONSHIP OF THE SPACE SHUTTLE PROGRAM TO LAND-USE PLANS, POLICIES, AND CONTROLS

Individual Space Shuttle activities are being undertaken at locations which have, for the most part, supported similar activities. In particular, existing rocket test facilities at Rocketdyne (Santa Susana, California), Thiokol/Wasatch (Promontory, Utah), NSTL (Bay St. Louis, Mississippi), and White Sands Test Facility (Las Cruces, New Mexico) will be used with minimal alteration for testing various rocket components of the Space Shuttle. For these tests, no new facilities are required, and no altered land use is anticipated. Some land-use changes will occur in preparation for Space Shuttle flight operations at KSC, DFRC, and VAFB; but these represent minor changes in government-owned lands already dedicated to similar uses. Detailed discussions of land-use aspects of the Space Shuttle Program are provided in the site-specific environmental impact statements (refs. 1-2 to 1-9). Highlights are as follows.

In the area of historic preservation, the continued utilization of NASA and contractor facilities assures continued preservation of archeological and historical sites located at those facilities. These include, but are not limited to, the Indian caves at Santa Susana, California (ref. 1-2); petroglyphs and rock houses at Thiokol/Wasatch, Utah (ref. 1-6); and the sugarhouse chimneys of the Lafon Plantation at the MAF, Louisiana (ref. 1-8). Apollo Launch Complex 39 at KSC, a site listed in the National Register of Historic Places, will be modified to accommodate Space Shuttle operations (ref. 1-5). NASA, the Florida state historic preservation officer, and the Advisory Council on Historic Preservation have agreed in a joint memorandum, in accordance with procedures for compliance with Section 106 of the National Historic Preservation Act of 1966, that the methods to be used in the modification will satisfactorily mitigate any adverse effect (ref. 3-1).

Continued agreements for multiple use of lands are similarly assured, ranging from agreements with other government agencies (e.g., the Fish and Wildlife Service, which manages the Merritt Island Refuge at KSC, and the National Park Service) to usage agreements with individuals for grazing, farming, or timber harvest on many of the sites.

For the most part, restrictions placed on privately held lands which have been acquired through easements, permits, or other authorizations, such as the acoustical buffer zone at the NSTL, will be upheld.

Public beaches and/or access to these beaches at both KSC and VAFB will be closed for brief periods before and during launch of the Space Shuttle. While this does constitute a land-use restriction, the interference is of minimum duration; and the recreational value of observing the launch from another near-by location may be expected to outweigh the restricted use of a small section of beach. Additionally, other near-by beaches at both locations will be unrestricted.

At the VAFB Space Shuttle launchsite, railroad activity exists between the base and the ocean. Before Space Shuttle launch, launch operations personnel must establish that the railroad along the coast is

not being used. The periods of railroad activity adjacent to the base are predictable and should create no severe problems for Space Shuttle launch operations.

Before Space Shuttle launches at KSC or VAFB, both air and sea advisories will be issued. Aircraft will be restricted from flying in the KSC and VAFB areas during Space Shuttle launches and will also be advised not to fly near or through the Space Shuttle exhaust cloud for a period usually exceeding an hour after launch. Before Space Shuttle launch, boats, ships, and aircraft at sea will be advised to stay clear of zones where sonic boom focusing is expected to occur and where SRB and External Tank reentry is predicted. In general, air and sea space restrictions are common to the affected areas because space activities at both the KSC and VAFB launchsites have been commonplace for many years. However, the pilot's advisory to avoid the Space Shuttle exhaust cloud is new.

In summary, the activities of the Space Shuttle Program are not expected to conflict with existing land-use plans, policies, and controls. Land to be used to support the Space Shuttle Program has previously been utilized for other space program activity. Air and sea space restrictions during launch will be similar to those now in practice for expendable launch vehicles.

4. POSSIBLE ENVIRONMENTAL EFFECTS OF THE SPACE SHUTTLE PROGRAM

4.1 Introduction

The activities of the Space Shuttle Program include the development and flight phases. Until the flight phase is reached, the program activities are site-specific (their environmental impacts have been evaluated in the various statements). The environmental effects of the Space Shuttle during the flight phase are not covered in the site-specific environmental statements; these effects are the principal subject of this environmental statement. However, to provide an overall view of the program and its environmental impact, all activities of the Space Shuttle Program are discussed herein. Brief reviews of site-specific effects are provided to highlight the potential adverse effects presented in the respective local environmental impact statements. The mitigating actions to be taken to reduce potential adverse effects will also be reviewed as appropriate.

The Space Shuttle Program may affect the quality of the human environment during launch and recovery operations, crew training, rocket engine test firings, launchsite development, and hardware manufacturing activities. This section includes impacts on air quality in the lower and upper atmosphere, water quality, noise, sonic boom, and cultural effects.

The approach used in discussing the possible environmental effects is to describe the action and its effects on the environment, followed by a comparison with allowable standards or guidelines, where such exist. The normal planned impacts associated with the physical effects of the Space Shuttle are discussed in sections 4.2 through 4.5. Unplanned events, such as accidents, are covered in section 4.6. The less tangible effects on human culture are discussed in section 4.7. Aspects involving human health and safety and effects upon terrestrial and aquatic life are discussed appropriately in each section.

4.2 Air Quality

The atmosphere near the surface of the Earth is affected by many Shuttle-related activities, including manufacturing, development, testing, and launch. Higher layers of the atmosphere are affected by Space Shuttle launch operations since exhaust products are released all the way from ground level up to the ionosphere at 160-km (100-mile) altitude. It is helpful to categorize the air quality effects by the atmospheric layer in which they occur, since the effects in each layer differ significantly. These layers include the lower atmosphere (0 to 13 km, or 0 to 8 miles), the stratosphere (13 to 50 km, or 8 to 31 miles), the mesosphere (50 to 80 km, or 31 to 50 miles), and the ionosphere (above 80 km). The altitude of the lower boundary of the stratosphere changes somewhat with latitude and season. The value of 13 km was chosen as a typical average value for KSC and VAFB (ref. 4-1). Figure 4-1 illustrates the relative positions of these atmospheric layers.

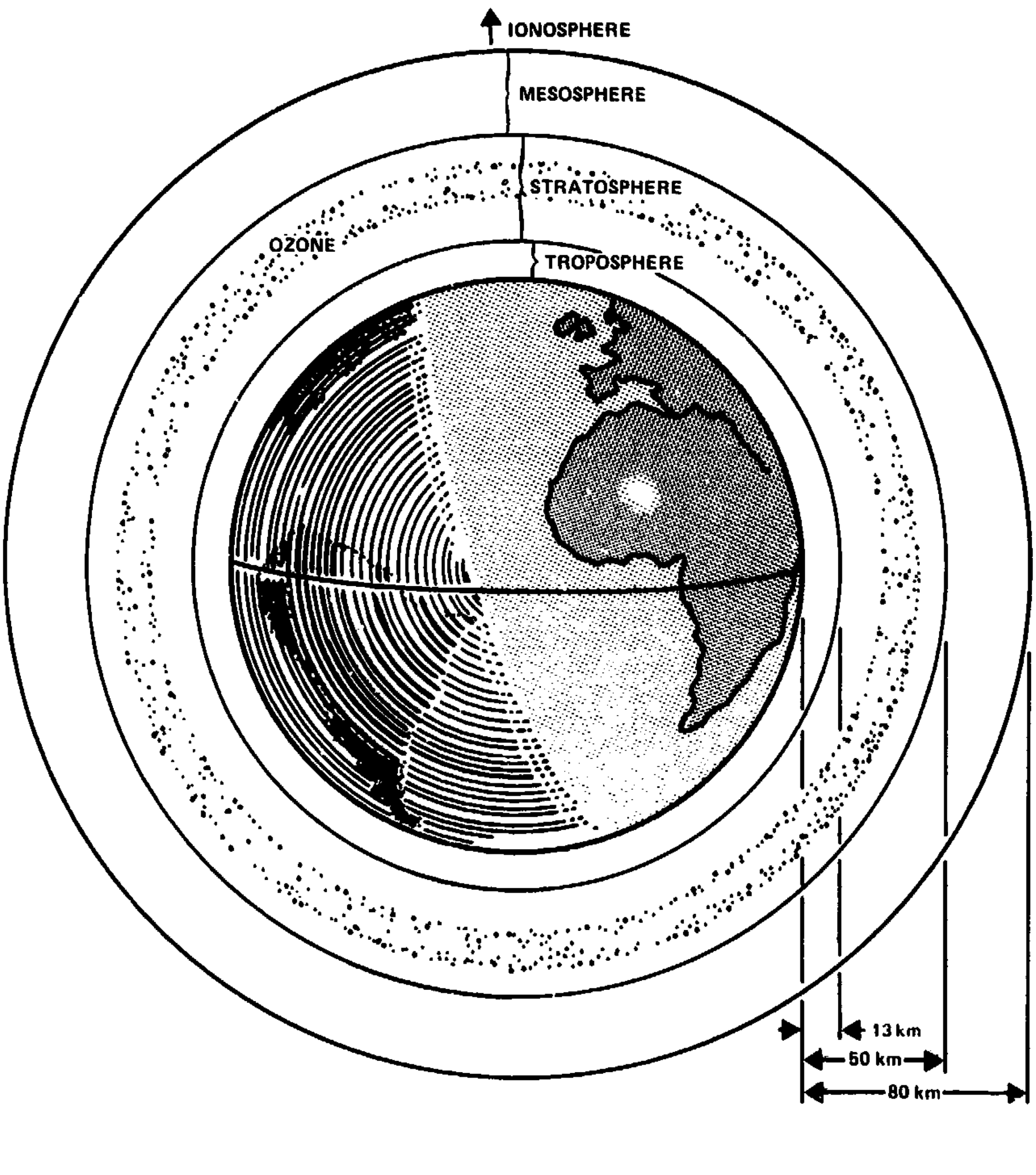

Figure 4-1.-- Locations of the troposphere, stratosphere, mesosphere, and ionosphere atmospheric layers.

The environmental effects in the lower atmosphere are concerned principally with toxic substances released into the air. In the stratosphere, the major concern is with the ozone layer. Exhaust products released into the mesosphere could diffuse downward and affect the ozone layer or upward and affect the ionosphere. In the ionosphere, changes in electron concentration are of interest. These effects are discussed in the following sections, beginning with the lower atmosphere and ending with the ionosphere.

4.2.1 Air Quality of the Lower Atmosphere

The Space Shuttle Program can affect the air quality of the lower atmosphere during the construction and operation of support and manufacturing activities; transportation of hardware and propellants; and the performance of engine tests, crew flight training, and launch operations.

The more significant effects arise principally from Space Shuttle launch operations and test firings. The air quality effects resulting from other activities are also discussed briefly. Details concerning these activities can be found in the appropriate environmental impact statements (refs. 1-2 to 1-9).

4.2.1.1 Space Shuttle Launch

The Space Shuttle flight system will be powered by chemical solid rocket motors and liquid rocket engines. The types of propellants to be used by the Space Shuttle are listed in tables 8-1 and 8-2.

The main environmental effect at launch arises from combustion of the Space Shuttle SRM's. Table 4-1 lists the major chemical species emitted by the Space Shuttle's rocket engines at the nozzle exit plane and for a plane 1 km (0.6 mile) downstream from the nozzle. The difference between the two sets of figures reflects the effect of afterburning within the rocket plume.

Combustion products are released into various layers of the atmosphere as the vehicle gains altitude during launch. Table 4-2 shows the altitude distribution of combustion products in selected atmospheric layers. Afterburning has been included in the calculations.

The bulk of the Shuttle combustion products is released into the troposphere. In the middle and upper troposphere, the exhaust products are deposited in a thin column because of the relatively high velocity of the vehicle there. This column quickly mixes and dissipates. At lower altitudes (near the surface), a cloud of exhaust products is generated. This "ground cloud" disperses slowly and has been the subject of extensive analysis.

In a normal launch, the ground cloud is formed at the base of the launch platform; it includes hot exhaust products from the SRM's, the main liquid propulsion engines, steam from launch platform cooling and acoustic

TABLE 4-1.-- EXHAUST PRODUCTS FOR NORMAL BURN[a]

(Percent by weight of nozzle exit plane flow)

Product	Nozzle exit plane	Plane 1 km downstream[b]
SRM (total mass flow ~9400 kg sec^{-1} for 2 motors)		
Hydrogen chloride	21.2	18.9
Chlorine (Cl_2)	0	2.1
Chlorine (Cl)	.3	.03
Nitric oxide	0	1.3
Nitrogen peroxide	0	.02
Carbon monoxide	24.1	.07
Carbon dioxide	3.4	41.2
Hydrogen	2.1	0
Hydroxyl and atomic hydrogen	.02	0
Nitrogen	8.7	(c)
Water	9.3	28.6
Aluminum oxide	30.1	30.1
Aluminum chloride	.02	.02
Iron chloride	.97	.97
Total	100.0	[d]123.3
Orbiter main engines (total mass flow ~1410 kg sec^{-1} for 3 engines)		
Water	95.9	128
Hydrogen	3.5	0
Argon, nitrogen, other	.6	.6
Total	100.0	[d]128.6

[a]This table is from reference C-5 (numerical errors in the draft environmental impact statement are corrected; there is no change in the conclusion).

[b]Afterburning is complete.

[c]It is assumed to be part of air.

[d]Total is greater than 100% because of chemical addition of air to form water, nitric oxide, and carbon dioxide.

TABLE 4-2.-- EXHAUST PRODUCTS EMITTED BY THE SPACE SHUTTLE VEHICLE INTO SELECTED ATMOSPHERIC LAYERS[a]

(From reference C-5)

Atmospheric layer	Altitude range[b]	Quantity of exhaust products, kg						
		Hydrogen chloride	Chlorine	Nitric oxide	Carbon monoxide	Carbon dioxide	Water[d]	Aluminum oxide
Surface boundary layer	0 to 500 m (0 to 1640 ft)	24 666	2741	1697	131	55 075	45 674	39 284
Troposphere	0.5 to 13 km (0.3 to 8 miles)	78 517	9657	4618	839	172 570	152 677	126 385
Stratosphere	13 to 50 km (8 to 31 miles)	59 732	11 727	293	2198	147 684	146 393	110 304
Lower mesosphere	50 to 67 km (31 to 41 miles)	0	0	[c]0	0	0	15 542	0
Mesosphere/ thermosphere	Above 67 km (Above 41 miles)	0	0	0	0	0	149 045	0

[a]Numerical errors in the draft Environmental Impact Statement are corrected; there is no change in the conclusions.

[b]U.S. customary units are given parenthetically.

[c]Production of nitric oxide by afterburning ceases between 45 and 60 km.

[d]This water is emitted by the SRM boosters and the Orbiter's main engines.

damping water injection, and some sand and dust drawn into the cloud from the platform area. Because of the high temperature of the gas cloud, buoyancy effects cause it to rise to an altitude of 0.7 to 3 km (0.4 to 1.8 miles), where it stabilizes because of the cooling of the gases. Although the amount of exhaust products contained in the ground cloud is a function of the local meteorology (principally the depth of the surface transport layer), it is typically calculated to be that due to approximately the first 20 sec of burn time of the Space Shuttle engines. This figure is arrived at by considering the ground cloud to be formed by the exhaust cloud emitted through the flame trench for the first 10 sec after ignition plus the column of exhaust products formed during the following 10 sec (ref. 4-2). The amounts of the principal exhaust constituents in a typical ground cloud at stabilization are estimated to be as follows.

Species	Amount, kg
Aluminum oxide	56 100
Carbon monoxide	240
Hydrogen chloride	35 200
Water	65 300
Nitrogen oxides	2 300
Carbon dioxide	76 800
Chlorine	4 000

The actual amounts in any given ground cloud will vary to a degree (depending on the surface conditions prevailing at the time of launch); this variance is considered in the models describing cloud dispersion.

The concentration of these species within the stabilized ground cloud is greatly reduced by mixing with the ambient air (approximately 99 percent air) and with steam from the water sprays used for launch platform cooling and acoustic damping. Once the cloud has reached the stabilization altitude, it will disperse, grow in size becaue of atmospheric diffusion, and move with the prevailing winds at that altitude. The dispersion of the ground cloud was predicted by the NASA/MSFC rocket exhaust effluent diffusion (REED) program. (See appendix C and ref. 4-2).

Of the major exhaust constituents, hydrogen chloride, chlorine, and aluminum oxide are the air pollutants of concern. Nearly all of the carbon monoxide is oxidized to carbon dioxide in the plume at low altitudes as shown in column 2 of table 4-1. Airborne measurements taken through the ground cloud formed during Titan-III launches (the Titan-III uses a similar SRM) confirm the low carbon monoxide values, typically below the 1-ppm detection level of the instrumentation used, and the low-chlorine values. The effect of the deluge water is to lower the temperature of the plume, which reduces the amount of afterburning during the initial period of launch. However, thermochemical calculations show the the plume temperature is still sufficient to convert the carbon monoxide to carbon

dioxide and that the amounts of nitric oxide and chlorine formed are slightly lower than the weight percentages quoted in table 4-1 (ref. 4-3). This effect is not important because most the ground cloud is generated after the Shuttle lifts off the launch pad (ref. C-5).

Three areas of environmental concern are associated with the ground cloud: toxic substances from the ground cloud, acidic rain, and inadvertent weather modification. These topics are treated in detail in the following paragraphs.

4.2.1.1.1 Potentially Toxic Substances from the Ground Cloud

The surface and airborne concentrations of ground cloud constituents have been predicted by using a mathematical model of the cloud. This model has been tested against Titan exhaust clouds and found to be a conservative model because it predicts higher values than those actually observed. A description of the model is given in appendix C.

The model was used to estimate the potential effects of the Space Shuttle ground cloud by calculating test cases for a variety of meteorological conditions. The results of such calculations for KSC are shown in figure 4-2, which shows the peak concentrations of hydrogen chloride and aluminum oxide experienced at ground level for various distances from the launch pad. For the calculation of the curves shown in this figure, climatological data were selected for 45 days spaced approximately a week apart during 1969. In this way, data representing the entire year are included. Whenever possible, data from the Wednesday morning soundings were used. Figure 4-2 shows only the envelope of the 45 cases calculated. Details of the case which gave the highest hydrogen chloride concentrations are provided in table 4-3 (ref. 4-2).

The largest value of hydrogen chloride concentration found for any of the cases (March 18, 1969) was 3.9 ppm. The average of the peak hydrogen chloride concentrations found for the 45 cases was 1.44 ppm. The smallest hydrogen chloride peak concentration found was about 0.5 ppm (March 15, 1969, and February 12, 1969).

Dosage of hydrogen chloride is defined as the concentration integrated over the time of exposure. The guidelines for dosage are usually expressed in terms of a mean concentration over a specified period of time. Thus, 4 ppm of hydrogen chloride over a 10-min period would correspond to a dosage of 40 ppm-min or 2400 ppm-sec. The maximum dosage predicted for the 45 cases was 731 ppm-sec, corresponding to an average concentration of 1.22 ppm over a 10-min period.

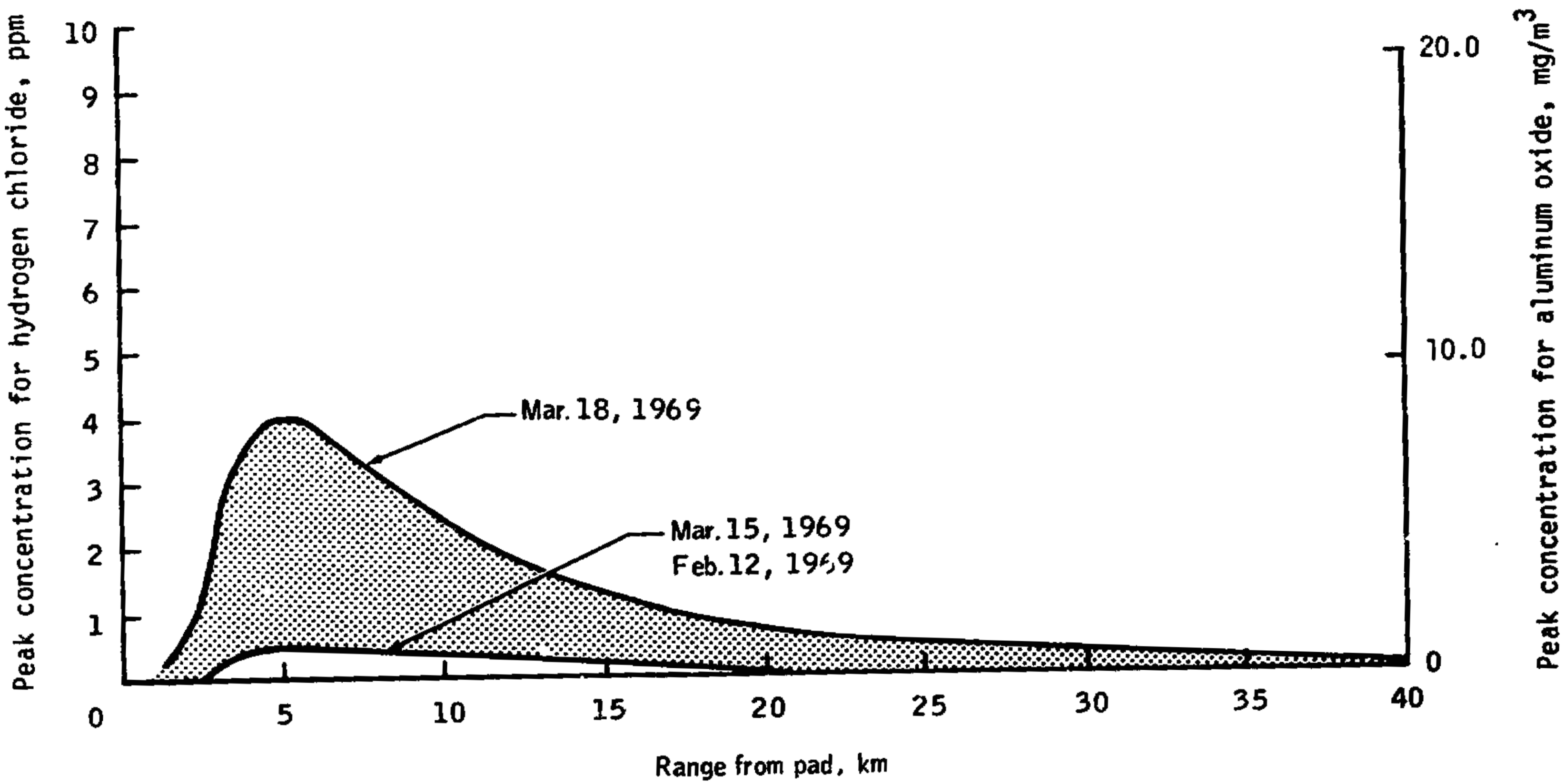

Figure 4-2.-- Preliminary Space Shuttle air quality predictions.

TABLE 4-3.-- SURFACE MAXIMUM CENTER-LINE HYDROGEN CHLORIDE CALCULATIONS FOR A NORMAL LAUNCH AT KENNEDY SPACE CENTER

(Model 3, 7 p.m., March 18, 1969)

Range, m	Azimuth bearing, deg	Maximum peak concentration, ppm	Maximum dosage, ppm-sec	Approximate 10-min time - mean concentration, ppm	Time of cloud passage, sec	Average cloud concentration, ppm
1 250	138.7	0.011	1.618	0.003	244.748	0.007
2 500	138.3	1.220	179.474	.299	252.349	.711
3 750	138.0	3.264	515.027	.858	270.713	1.902
5 000	137.7	[a]3.942	684.405	1.141	297.858	2.298
6 250	137.6	3.783	[a]731.351	[a]1.219	331.631	2.205
7 500	137.5	3.333	719.254	1.198	370.225	1.943
8 750	137.4	2.826	679.242	1.130	412.286	1.648
10 000	137.4	2.361	628.775	1.043	456.859	1.377
11 250	137.3	1.969	577.697	.953	503.275	1.148
12 500	137.3	1.652	530.668	.867	551.071	.963
13 750	137.3	1.399	489.127	.790	599.915	.815
15 000	137.3	1.196	453.008	.719	649.572	.697
16 250	137.2	1.033	421.622	.657	699.869	.602
17 500	137.2	.901	394.223	.601	750.677	.525
18 750	137.2	.792	370.137	.550	901.898	.462
20 000	137.2	.701	348.813	.505	853.459	.409
21 250	137.2	.625	329.810	.465	905.302	.364
22 500	137.2	.560	312.765	.429	957.380	.327
23 750	137.2	.505	297.380	.396	1009.657	.295
25 000	137.1	.458	283.445	.366	1062.104	.267

[a]Maximum.

The concentrations of carbon monoxide, chlorine, and nitrogen oxides are proportional to the hydrogen chloride concentration. Peak concentrations at KSC for that case were predicted to be the following.

Hydrogen chloride, ppm	3.9
Chlorine, ppm	0.4
Nitric oxide, ppm	0.2
Nitrogen dioxide, ppm	0.004
Carbon monoxide, ppm	0.02
Aluminum oxide, mg/m^3	10

Generally similar results have been obtained for VAFB (ref. 1-9). Some details on exhaust product concentrations at VAFB are as follows: Estimates of the peak hydrogen chloride center-line concentrations at ground level from periodic launches throughout the year using meteorological data from VAFB (taken at 0400 Pacific standard time, when the atmosphere is generally most stable) on 48 days in 1974 are displayed in table 4-4. The maximum peak center-line concentration calculated is 3.4 ppm, and the maximum 10-min time-mean center-line concentration is approximately 2 ppm. The maximum dosage of any of the 48 cases was approximately 1200 ppm-sec. In every case, the maxima are predicted to occur within about 10 km (6 miles) of the launchsite, either on base or over the ocean. Based on the previously mentioned exhaust composition, the potential toxic substances, carbon monoxide, carbon dioxide, chlorine, and nitrogen oxides are predicted to represent small fractions of their allowable concentration guidelines.

As discussed in appendix C, the model predictions for aluminum oxide are consistently high by factors of 5 to 70 based on the series of tests conducted during Titan launches. Thus, the actual concentration of aluminum oxide expected is in the range of 2.0 to 0.14 mg/m^3 rather than the 10 mg/m^3 quoted in the list of the preceding paragraph. Because the duration of exposure to aluminum oxide particulates is expected to be similar to that for hydrogen chloride (i.e., in the range from 1 to 4 min), the maximum 24-hr average concentration is 0.006 mg/m^3. This value does not exceed the estimatd 24-hr average primary and secondary standards for particulates of 0.26 and 0.15 mg/m^3, respectively, as outlined below.

It should be noted that the model used for the exhaust cloud calculations is the subject of continued research by NASA. As improved model formulations are developed, revised predictions will be published.

The model may also be used to calculate concentrations inside the airborne ground cloud. These model calculations predict that concentrations of hydrogen chloride in the high-altitude center of the Space Shuttle exhaust ground cloud would initially be around 100 ppm; however, the concentrations in the high-altitude center of the cloud would fall below the threshold limit of 8 ppm of hydrogen chloride under typical atmospheric conditions before the exhaust cloud is transported beyond the launch area. This area is normally cleared of air traffic during launch operations; therefore, these concentrations aloft should not present an air quality problem. Aircraft measurements of Titan clouds (ref. 4-2) bear out these calculations. These show that under normal weather conditions, the incloud concentration drops quickly below 4 ppm. Under certain atmospheric conditions, part of

TABLE 4-4.-- MAXIMUM CENTER-LINE HYDROGEN CHLORIDE CALCULATIONS FOR A SPACE SHUTTLE NORMAL LAUNCH AT VANDENBERG AIR FORCE BASE

(Model 3; 48 selected cases during 1974)

Date (1974)	Azimuth bearing, deg	Cloud stabilization height, m	Horizontal distance to maximum ground-level concentration, m	Maximum peak concentration, ppm	Approximate 10-min time-mean concentration, ppm
Wed., 9 Jan.	131	1014	3750	0.22	0.26
Tues., 15 Jan.	354	824	3505	1.05	.41
Mon., 21 Jan.	172	1094	5500	1.27	.28
Mon., 28 Jan.	170	1024	4250	.15	.03
Mon., 4 Feb.	155	784	4728	1.05	.93
Sun., 10 Feb.	31	1094	6000	.39	.35
Sat., 16 Feb.	140	854	2943	.41	.27
Sat., 23 Feb.	213	894	4960	.38	.05
Sat., 2 Mar.	75	1214	5000	.43	.10
Sat., 9 Mar.	185	1139	4750	.14	.05
Fri., 15 Mar.	190	964	5500	.68	.37
Tues., 26 Mar.	41	1084	5250	.52	.22
Mon., 1 Apr.	142	974	3750	.24	.07
Sun., 7 Apr.	190	994	6500	2.69	.28
Sat., 13 Apr.	198	1040	4283	.18	.07
Fri., 19 Apr.	159	1305	6500	.79	.18
Fri., 26 Apr.	135	1043	4879	.96	.17
Thur., 2 May	152	944	4860	1.01	.37
Wed., 8 May	155	854	4156	1.39	.86
Tues., 14 May	159	879	5322	2.54	.53
Wed., 22 May	199	859	5132	.67	.27
Wed., 29 May	162	979	5527	1.65	.57
Tues., 4 June	177	819	3893	.35	.10
Tues., 11 June	186	829	4846	3.08	1.22
Mon., 17 June	93	1204	4633	.19	.13
Wed., 26 June	202	729	3062	.66	.11
Wed., 3 July	283	919	5000	.63	.19
Wed., 10 July	113	1216	5668	.44	.38
Wed., 17 July	162	734	3204	.86	.50
Wed., 24 July	256	764	3087	.46	.50
Wed., 31 July	289	834	2792	.24	.24
Tues., 6 Aug.	173	814	4799	2.04	.33
Tues., 13 Aug.	174	1054	4266	.17	.19
Mon., 19 Aug.	165	804	4178	2.81	.51
Sun., 25 Aug.	303	969	5498	.86	.67
Sat., 31 Aug.	101	854	4646	.93	.50
Sun., 8 Sept.	195	794	4343	.46	.10
Mon., 16 Sept.	208	864	4775	.52	.15
Tues., 24 Sept.	157	973	4499	.36	.23
Fri., 4 Oct.	164	1074	5411	1.04	.50
Sun , 13 Oct.	238	774	4592	2.62	1.97
Mon., 21 Oct.	175	939	4264	.32	.19
Fri., 1 Nov.	140	1484	6004	.46	.25
Sat., 9 Nov.	187	1009	7028	2.26	.27
Sat., 16 Nov.	183	899	5799	.31	.11
Sat., 23 Nov.	207	939	7521	3.38	.41
Sat., 30 Nov.	325	964	4964	.99	.18
Sun., 8 Dec.	66	824	3669	.59	.12

[a]Cases pertain to meteorologic conditions at 0400 Pacific standard time on the tabulated date. Prediction data were developed using the NASA/MSFC multilayer diffusion model.

the exhaust cloud can be trapped in a stagnant layer aloft, and typical dispersion does not occur. In one instance, when a strong inversion layer was present, the cloud was "trapped," and concentrations of up to 40 ppm were measured inside the cloud.

a. Air Quality Guidelines for the Ground Cloud

The human air quality guidelines for Space Shuttle-related pollutants are given in table 4-5 (a) and (b). These are composed of the air quality standards set by the Environmental Protection Agency (EPA) for particulates and the recommendations made by the Committee on Toxicology of the National Academy of Sciences (NAS)/National Research Council (NRC) for hydrogen chloride, carbon monoxide, chlorine, MMH, hydrazine, and nitrogen oxides (refs. 4-6 to 4-11). The EPA national primary ambient air quality standards define levels of air quality judged necessary to protect public health with an adequate margin of safety. The EPA national secondary ambient air quality standards define levels of air quality judged necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

The Committee of Toxicology established short-term public limits (STPL's) and public emergency limits (PEL's). The STPL's relate to predictable exposures and sources arising from single or occasionally repeated events; the STPL's keep below the level of irritation to the moist mucous membranes of the upper respiratory tract. The levels quoted are time-weighted averages not considered to present any health hazard (ref. 4-7). The PEL relates to accidents (i.e., the escape of pollutants in an uncontrolled manner at unpredicted times and places); the PEL's are also time-weighted averages and recognize the possibility of some temporary discomfort although the effect is reversible with no serious sequel (ref. 4-7). The PEL values for hydrogen chloride are tentative since the effects of a preexisting pulmonary disease condition are not known.

The STPL's and PEL's are time-weighted averages. Excursions above the limit must be counterbalanced by an equal time below the limit. They are further governed by maximum excursion limits. In the case of hydrogen chloride, the Committee of Toxicology recommended on December 6, 1972 (ref. 10-1), pending the generation and evaluation of new data, that an excursion by a factor of 2 above the guide values may be tolerated for no more than 5 min.

This means that for no more than 5 min, exposure to hydrogen chloride may be as high as 8 ppm; this must be counterbalanced, in the case of the 10-min limit, by cessation of exposure to hydrogen chloride. Under these limits, there can be no predictable exposure to more than 8 ppm, no matter how short the time. This maximum excursion has been called the ceiling limit. The PEL's are also governed by the concept of time-weighted averages, with an excursion factor of 2. In the case of an accident, an exposure for 5 min to 14 ppm would be balanced by cessation of exposure. No accidental, unpredictable exposure to more than 14 ppm is recommended, no matter how short the time. The same ceiling limit concept has been applied to the PEL's.

TABLE 4-5.-- EXPOSURE LIMITS FOR SELECTED ROCKET ENGINE COMBUSTION PRODUCTS FOR MAN

(a) Standards set by the Environmental Protection Agency

Product	Reference	Type of limit	Duration	Time-weighted average concentration, mg/m^{-3}	Ceiling limits, mg/m^{-3}
Aluminum oxide	4-6	National primary standards (for public health)	Annual geometric mean	0.075	--
			Max. 24-hr concentration, not to be exceeded more than once/yr	--	0.26
		National secondary standards (for public welfare)	Annual geometric mean	.06	--
			Max. 24-hr concentration, not to be exceeded more than once/yr		.15

TABLE 4-5.-- Concluded.

(b) Recommendations of the Committee on Toxicology

Product	Reference	Type of limit	Duration	Time-weighted average concentration, ppm	Ceiling limits, ppm
Hydrogen chloride	4-7	STPL	10 min 30 min 60 min 1 hr daily 5 hr/day (3 to 4 days/mo)	4 2 2 2 .7	8 4 4 4
		PEL	10 min 30 min 60 min	7 3 3	14 6 6
Carbon monoxide	4-8	STPL	10 min 30 min 60 min 4 to 5 hr/day (3 to 4 days/mo)	90 35 25 15	135 53 38
		PEL	10 min 30 min 60 min	275 100 60	275 100 60
Chlorine	4-9	STPL	10 min 30 min 60 min	1 .5 .5	3 1 1
		PEL	10 min 30 min 60 min	3 2 2	3 2 2
MMH	4-10	STPL	10 min 30 min 60 min	9 3 1.5	90 30 15
		PEL	10 min 30 min 60 min	90 30 15	90 30 15
Hydrazine	4-10	STPL	10 min 30 min 60 min	15 10 5	30 20 10
		PEL	10 min 30 min 60 min	30 20 10	30 20 10
Nitrogen oxides	4-11	STPL	10 min 30 min 60 min	1 1 1	1 1 1
		PEL	10 min 30 min 60 min	5 3 2	5 3 2

Although the Committee on Toxicology referred only to the case of hydrogen chloride in its discussion, the same concept has been applied to all the toxicants listed in table 4-5 in the absence of any other guidelines.

The available exposure levels for animals and their corresponding effects are summarized in table 4-6 (refs. 4-12 to 4-15). The results of definitive tests involving exposure levels to aluminum oxide dust are limited at this time. One study showed there were no toxic effects up to 14 days after exposure to 478 mg/m^3 of alumina (aluminum oxide) and no mortality for rodents (ref. 4-13). The same researchers reported no synergistic effects for a combined exposure of hydrogen chloride and aluminum oxide and chlorided aluminum oxide.

A comprehensive literature survey on the effects of hydrogen chloride and aluminum oxide on plants has been published by Lerman (ref. 4-16). Some results for plant species grown in the VAFB launch area are shown in table 4-7 (from ref. 4-12). General information on various other plants is given in table 4-8 (ref. 4-15).

b. Predicted Ground-Cloud Effects vs. Air Quality Guidelines for Human Exposure

The surface concentrations of hydrogen chloride, chlorine, nitric oxide, nitrogen dioxide, and aluminum oxide estimated for the Shuttle ground cloud are all less than the human exposure limits, both in terms of maximum concentration and duration of exposure. The predicted concentrations are also considerably less than those noted as causing injury to animals. Some sensitive plant species may react to exposures of diluted hydrogen chloride from the exhaust cloud by traces of discoloration.

The interior of the airborne cloud at altitudes of several thousand meters may have concentrations of hydrogen chloride in excess of toxic levels, provided that the cloud is "trapped" in an inversion layer. Such trapped clouds may persist for an hour or two after launch. The occurrence of trapped clouds is predictable in the sense that weather conditions favorable for their formation are well-defined. Whenever possible, launches will be made at times when meteorological conditions favor minimum effects on air quality.

4.2.1.1.2 Acidic Rain

Acid rain, as it is most generally known, is a widespread, low-level form of pollution occurring as a result of burning fossil fuels. The mechanisms by which rains are becoming progressively more acidic are not totally understood. The increase has been assumed to be largely due to increased outputs of sulfur dioxide from anthropogenic sources (ref. 4-17). In Scandinavian countries and in the northeastern portion of the United States, rainwater consistently has a pH[4] in the range of 3.0 to 4.0. In the United States, values as low as 2.1 have been recorded (ref. 4-17). A raindrop containing no impurities but being in equilibrium with atmospheric carbon dioxide will attain a pH of 5.7. The natural pH of rain in the

TABLE 4-6.-- SUMMARY OF REPORTED EFFECTS OF HYDROGEN CHLORIDE INHALATION ON ANIMAL LIFE

(Reference 4-12)

Species	Concentration, ppm	Exposure time	Effects or comments	Reference
Rabbits	4300	30 min	Fatal in some cases because of laryngeal spasm, laryngeal edema, or rapidly developing pulmonary edema	4-13
Guinea pigs	4300	30 min	Fatal in some cases because of laryngeal spasm, laryngeal edema, or rapidly developing pulmonary edema	4-13
Cats	3400	90 min	Death after 2 to 6 days	4-13
Rabbits	3400	90 min	Death after 2 to 6 days	4-13
Guinea pigs	3400	90 min	Death after 2 to 6 days	4-13
Rats	3100	60 min	50% mortality rate	4-13
Mice	2600	30 min	50% mortality rate -- hydrogen chloride gas	4-14
Mice	2100	30 min	50% mortality rate -- hydrogen chloride aerosol	4-14
Cats	1350	90 min	Severe irritation, dyspnea, and clouding of the cornea	4-13
Rabbits	1350	90 min	Severe irritation, dyspnea, and clouding of the cornea	4-13
Guinea pigs	1350	90 min	Severe irritation, dyspnea, and clouding of the cornea	4-13
Mice	1110	60 min	50% mortality rate	4-11
Rabbits	670	2 hr	Fatal in some cases	4-13
Guinea pigs	670	2 hr	Fatal in some cases	4-13

Table 4-6.-- Concluded.

Species	Concentration, ppm	Exposure time	Effects or comments	Reference
Rabbits	300	6 hr	Corrosion of the cornea and upper respiratory irritation	4-13
Guinea pigs	300	6 hr	Corrosion of the cornea and upper respiratory irritation	4-13
Rabbits	100 to 140	6 hr	Only a slight corrosion of the cornea and upper respiratory irritation	4-13
Guinea pigs	100 to 140	6 hr	Only slight corrosion of the cornea and upper respiratory irritation	4-13
Rabbits	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose	4-13
Guinea pigs	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose	4-13
Pigeons	100	6 hr/day for 50 days	Slight unrest and irritation of the eyes and nose	4-13
Monkey	33	6 hr/day 5 days/wk for 4 wk	No immediate toxic effects and no pathological changes	4-13
Rabbits	33	6 hr/day 5 days/wk for 4 wk	No immediate toxic effects and no pathological changes	4-13
Guinea pigs	33	6 hr/day 5 days/wk for 4 wk	No immediate toxic effects and no pathological changes	
Rabbits	60	5 min	Cessation of ciliary activity without recovery	4-13
Rabbits	30	10 min	Cessation of ciliary activity without recovery	4-13
Bobwhite quail eggs	168 to 260	15 min	50% mortality rate	4-15
Chicken eggs	168 to 260	15 min	50% mortality rate	4-15

TABLE 4-7.-- INJURY SYMPTOMS OF EIGHT PLANT SPECIES EXPOSED TO HYDROGEN CHLORIDE GAS AT CONCENTRATIONS RANGING FROM 1 TO 25 PPM FOR 20 MINUTES

(From reference 4-12)

Plant	Dosage of hydrogen chloride concentration		
	15-25 ppm (300-500 ppm-min)	7-14 ppm (140-280 ppm-min)	1-6 ppm (20-120 ppm-min)
Aster	Temporary wilting; extensive interveinal bronzing on lower leaf surface; necrosis of young tissue	Interveinal bronzing on lower surface; trace of necrosis	Trace of necrotic spots on young leaves
Calendula	Temporary wilting; lower surface bronzing; discoloration necrosis; the younger the leaf, the more distal the damage	Bronzing of lower leaf surface; interveinal necrosis; marginal discoloration	Traces of lower surface bronzing
Centaurea	Extensive necrosis; rolling; speckling; temporary wilting; discoloration	Discoloration along the leaf margins; rolling	--
Cosmos	Extensive necrosis; extensive rolling; flower discoloration; tipburn of sepals	Tipburn; tip rolling	Tipburn
Marigold, dwarf	Severe necrosis of almost all leaves; rolling	Discoloration; necrosis of mid-aged leaves; some rolling	Traces of necrosis or discoloration
Marigold, Sen. Dirksen	Severe necrosis; extensive rolling; tipburn of sepals on flowers	Interveinal discoloration of mid-aged leaves; some rolling	Traces of necrosis or discoloration
Nasturtium	Interveinal bleached lesions; on younger leaves, marginal bleaching and rolling	Discoloration; necrotic speckling; rolling	Traces of discoloration
Zinnia	Bronzing on basal leaf portions; extensive necrosis and rolling on rest of leaf; occasional petal necrotic spots	Speckling; interveinal bronzing	Trace of lower surface bronzing

TABLE 4-8.-- SUMMARY OF THE REPORTED TOXIC EFFECTS OF HYDROGEN CHLORIDE EXPOSURE TO PLANTS

(From reference 4-15)

Species	Concentration, ppm	Exposure time	Effects or comments
Plants	10 to 50		No leaf damage
Plants	100 to 1000		Leaf damage
Sugar beets	10	Few hr	Threshold for marking
Viburnum seedlings	5 to 20	24 hr	Leaves rolled at the edges, withered, shrunk, faded, and necrotic
Beech	1000	1 hr	Local lesions produced
Oak	1000	1 hr	Local lesions produced
Maple	2000		Marginal leaf scorch
Birch	2000		Marginal leaf scorch
Pear	2000		Marginal leaf scorch
Viburnum seedlings	5 to 20	48 hr	Plants died
Larch	5 to 20	48 hr	Plants died
Fir	1000	1 hr	Local lesions formed
Spruce	2000	1 hr/day for 80 days	No apparent injury
Tomato plants	5	2 hr	Development of interveinal bronzing followed by necrosis within 72 hr after exposure
Liriodendron tulipifera	3	4 hr	Threshold for visible injury
Alnus glutinosa	6	4 hr	Threshold for visible injury
Prunus serotina	6	4 hr	Threshold for visible injury
Acer saccharum	7	4 hr	Threshold for visible injury
Acer platanoides	7	4 hr	Threshold for visible injury
Quercus rubrum	13	4 hr	No visible injury
Pinus strobus	8	4 hr	Threshold for visible injury
Pseudotsuga mantissii	10	4 hr	Threshold for visible injury
Abies balsamea	10	4 hr	Threshold for visible damage
Pinus abies	19	4 hr	Threshold for visible damage
Pinus nigra	18	4 hr	No visible damage
Thuja occidentalis	43	4 hr	No visible damage
Spruce seedlings	50	20 min	Death of plants

northcentral Florida region, which includes the KSC launchsite area, was measured during 1967 and 1968 to be 5.3 to 6.8.

The Shuttle cloud can lead to a special type of acidic rain caused by solution of the hydrogen chloride in rain. Depending on atmospheric conditions, the exhaust cloud may entrain enough water to generate a light rain or mist, encounter rain from a higher stratum cloud or spray blown out of a convective shower, or be sucked into a rain-generating cloud. The rain or mist precipitated from any of these occurrences is acidic.

Two incidents have been reported which involved acidic rain from solid rocket test firings or launches. The first incident occurred on June 17, 1967, when a solid propellant rocket motor 260 inches in diameter was static-test-fired in Dade County, near Homestead, Florida. The test was made during shower activity that was accompanied by winds averaging 10 kph (6 mph) gusting to 34 kph (20 mph). Acidic rain fell on lime and avocado groves 10 km (6 miles) from the firing and produced some damage to the fruit crop. The fruit was spotted and considered not salable. No information is available on the pH of the rains involved. The second incident occurred at KSC in September 1975 during the launch of the Viking-B spacecraft on a Titan Centaur launch vehicle (ref. 4-2). Thundershowers moved over the Titan exhaust cloud several minutes after the launch. A NASA environmental monitoring team located within the controlled area measured pH values ranging from 1 to 2. To gain a qualitative sense of the degree of acidity represented by these pH values, it may be helpful to note that the pH of vinegar is about 3.1 and that the pH of normal human stomach fluids is in the range of 1 to 2. The degree of acidity of the rain generated by the Space Shuttle or mist relative to the ambient local conditions and its predictability are the subjects of ongoing NASA research.

A preliminary acid rain model has been developed by NASA to represent a simple idealization of the real case (ref. 4-2). In this model, the hydrogen chloride column density in the Space Shuttle ground cloud is computed using the NASA/MSFC exhaust cloud model (appendix C). A steady rain is assumed to fall through the stabilized ground cloud at various distances from the launchsite. Rain pH curves bounding the expected range of rainfall rates, including meteorological regimes selected as being typical for the KSC area, are shown in figure 4-3 as a function of distance from the launchsite. This plot shows the column density of hydrogen chloride gas (expressed in terms of cm^3 of hydrogen chloride gas at standard temperature and pressure (STP) per cm^2 surface area) at the cloud center as a function of distance from the launchsite. Seven different meteorologies were used, each representing a typical pattern for KSC. Only the upper and lower of these seven curves are shown. The pH for rain after falling through the cloud at each column density of hydrogen chloride is shown by horizontal lines on the plot. Coefficients for the rate of hydrogen chloride gas solution in raindrops were estimated from laboratory measurements.

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[4]The pH factor is a measure of the acidity or alkalinity of a solution. Mathematically, it is the negative logarithm of the hydrogen ion concentration. A pH value of 7 is chemically neutral. Lower pH values are acidic; higher values are alkaline. A pH of 4 to 5 is weakly acidic; 0 to 1 is strongly acidic.

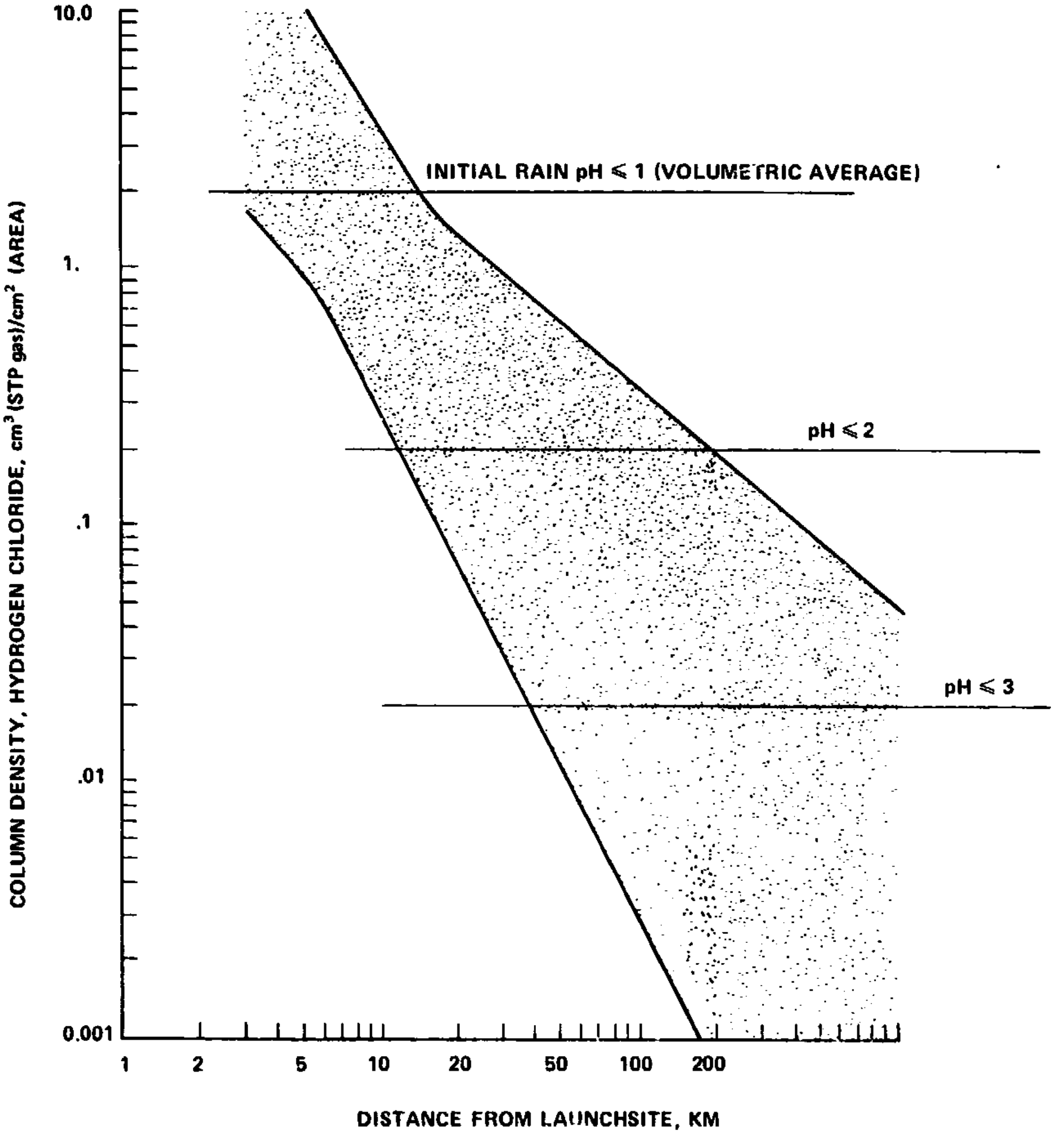

Figure 4-3.-- Predicted decay of acid rain potential for initial rain. Envelope applies for seven standard meteorologies involving Space Shuttle launches.

The indicated range of pH for each horizontal marker line implies variability with rainfall rate. The limiting pH value shown in each case corresponds to 25 mm of rain per hour; rainfall at 1 mm/hr should be 0.5 pH unit more acidic. Note that these pH's represent volumetric average maximum acidity levels for initial rainfall centered through the ground cloud. The final acidity is a function of progressive washout of the ground cloud; the diluting effect of subsequent rainfall; and, for rainwater in contact with the ground, the buffering capacity of the soil. Since the predictions were made for mass-conservative SRM clouds, absorption of hydrogen chloride at ground level and convective loss of hydrogen chloride near the cloud's upper boundary would decrease the predicted acidities, especially for distances greater than 100 km (60 miles) from the launchsite.

According to the data shown in figure 4-3, rain acidities of pH $\leq$ 1.0 are possible at distances ranging from 3 km (2 miles) to 15 km (9 miles) from the launchsite, depending on the meteorological conditions prevailing at launch.

Further work is continuing to improve the acidic rainfall model by consideration of more complex atmospheric conditions and airborne sampling of Titan-III ground clouds to determine potential surface/temporal distribution of rain acidity. A companion activity is establishing the existing rainfall activity and cataloging the local ecosystems and their characteristic behavior under acidic rainfall.

Acidic rain from the Shuttle exhaust cloud would be highly localized and temporary. Cumulative effects resulting from long-continued exposure as observed for industry-derived acidic rain, are not expected to occur. Based on the two acidic rain incidents mentioned above, the only environmental effect of Shuttle acidic rain would be to damage vegetation temporarily, provided that its acidity is high enough. This acidity is estimated to correspond to pH values of 1.0 or less. Under most meteorological conditions, acidic rain of this pH level would be confined to the launch area. Control of acidic rain in the general region of the launchsite can be achieved by the proper choice of launch time to match favorable meteorological conditions. Secondary effects of acid rain (trace metal and ground water changes) similar to those observed for widespread and continuous acid rain might occur, but the areal extent and duration of such effects are expected to be small and temporary because of the episodic nature of Shuttle-derived acid rain.

4.2.1.1.3 Inadvertent Weather Modification

The possibility for inadvertent weather modification by the Space Shuttle exhaust is difficult to assess. The potential for local weather modification by single Space Shuttle launches and the cumulative effect of 40 launches per year have been estimated (refs. 4-2 and 4-18) with the current state of knowledge in this field. The results (ref. 4-18) suggest that individual Space Shuttle ground clouds might modify the local weather for up to 2 days after liftoff. The area that could potentially be affected was estimated to be confined to an area less than 13 km (8 miles) in radius. Such modification could include either the intensification or the suppression of rainfall, depending on local conditions. Large-scale or long-range

weather modification is not expected. It was also concluded that the cumulative weather modification effect of 40 Space Shuttle launches per year was insignificant. Airborne measurements in Titan-III launch clouds are planned for checking the assumptions upon which the assessment was based. The choice of launch times to match favorable meteorological conditions, as in the case of acidic rain, could eliminate the possibility of weather modification.

4.2.1.2 Testing of the Solid Rocket Motors

A series of seven test firings of the SRM is planned at the Thiokol/Wasatch plantsite near Brigham City, Utah, during 1977 and 1978. These firings produce effects generally similar to those discussed for the Space Shuttle launch and are discussed in the environmental impact statement for this action (ref. 1-6). Areas of environmental concern include the effects of toxic gases in the cloud, acidic rain, and inadvertent weather modification.

The rockets burn approximately 500 000 kg (1 100 000 lb) of propellant within a 2-min period in each test. One firing is expected to release into the atmosphere the following.

Species	Amount, kg
Aluminum oxide	152 000
Carbon monoxide	Negligible
Hydrogen chloride	96 000
Water	145 000
Nitrogen oxides	7 000
Carbon dioxide	208 000
Chlorine	11 000

These hot gases rise to several thousand feet to form a ground cloud similar to that described for the Shuttle launch. The gas cloud drifts with the prevailing winds, dispersing rapidly as it moves.

The concentrations of hydrogen chloride, chlorine, nitrogen oxide, and aluminum oxide at ground level were calculated with the same cloud diffusion model as was used for the Space Shuttle ground cloud. The highest concentrations predicted for 23 representative meteorological cases (using Salt Lake City rawinsonde data) were as follows.

Aluminum oxide, mg/m^3	3.5
Hydrogen chloride, ppm . . .	1.7
Chlorine, ppm	0.1
Nitrogen oxide, ppm	0.15

The peak concentrations occur typically inside a 10-km (6-mile) radius downwind of the test site. The duration of the exposure depends on windspeed but varies between 2 to 7 min. The maximum 24-hr aluminum oxide concentration calculated does not exceed 0.02 mg/m^3, which is below the EPA primary and secondary 24-hr average allowable concentrations given in table 4-5.

The effects of these toxic materials on human health and safety and on flora and fauna have been examined in the site-specific impact statement (ref. 1-6). The conclusion reached in this impact statement was that no public health or safety problem would result from either normal or abnormal test firings.

Precipitation (rain or snow) scavenging of hydrogen chloride from the exhaust cloud could occur if the test were conducted during rain or snow. This possibility is to be eliminated by postponement of the test firing if a forecast exists for precipitation within 2 hr after the test.

The possibility of inadvertent weather modification is extremely difficult to assess, based on current incomplete understanding of this subject. However, no obvious effects at this site have been noted during 20 years of solid rocket propellant combustion.

The environmental impacts of the SRM tests are generally similar to those described for the Space Shuttle launch. A detailed treatment of the effects of the SRM tests on human health and safety, flora, and fauna is given in the site-specific statement (ref. 1-6).

4.2.1.3 Space Shuttle Liquid Engine Tests

The Orbiter's main propulsion engines, the OMS, and the RCS are extensively tested at various sites before delivery to the launchsites. The environmental effects of these tests have been considered and are detailed in the appropriate site-specific environmental impact statements (refs. 1-2, 1-4, and 1-7). Brief summaries follow.

4.2.1.3.1 Orbital Maneuvering System and Reaction Control System

The OMS and the RCS, as described in section 2.3.1.1.2, will be tested at the NASA White Sands Test Facility. This test site has been utilized for similar tests during past space program activity, and the proposed actions do not represent significant new additions or alterations to the testing activity at this site. Toxic propellant vapors from the test areas are vented to special burner systems or water-filled ponds and are not released directly to the atmosphere. Toxic fumes from the chemical laboratory are passed through air washers, and the resultant liquid is handled by the acid drains. Waste liquids from all areas are neutralized before release to the drainage system.

4.2.1.3.2 Orbiter's Main Propulsion Engines

The main engine of the Space Shuttle is tested at Santa Susana, California, and at Bay St. Louis, Mississippi. A brief on-pad firing is planned at KSC prior to the first launch. The quantity of propellant consumed in these tests is typically one-third of the propellant consumed in flight. The engine propellants produce only water vapor (96.5 percent) and free hydrogen (3.5 percent) from the combustion process. It does not

contribute any of the five primary pollutants to air; i.e., carbon monoxide, hydrocarbons, sulphur oxides, nitrogen oxides, and particulates.

The test sites have been utilized for similar tests during the entire national space program, and the proposed actions do not represent significant additions or alterations to the testing activity at these sites. Testing of the Orbiter's main propulsion engine is well under way at this time.

4.2.1.4 Space Shuttle Design, Development, and Engineering

4.2.1.4.1 Construction, Modification, and Operation of Support and Manufacturing Facilities

Construction and modification of facilities generate dust and vehicle emissions. Facility operations produce emissions from powerplants, worker's vehicles, cleaning and degreasing of parts, and open burning of solid waste propellant. The most significant operation is expected at the contractor plant (Thiokol/Wasatch). The total amount of waste propellant expected to be disposed of between 1976 and 1980, for all Thiokol/Wasatch programs, is estimated at 390 000 kg (860 000 lb). About 18 percent of this would result from the SRM DDT&E program casting activities. The quantities of potentially toxic constituents released for a typical waste SRM casting burn of 3175 kg (7000 lb) are as follows.

Species	Amount, kg
Aluminum oxide	905
Carbon monoxide	780
Hydrogen chloride	533
Water	317
Nitrogen	276
Chlorine	115
Carbon dioxide	90
Hydrogen	68
Other	91
Total	3175

These quantities are released before the afterburning process. Chemical reactions that can continue during afterburning should significantly reduce the carbon monoxide and chlorine concentrations (ref. 1-6). The highest peak instantaneous concentrations of hydrogen chloride and aluminum oxide to be expected from 23 meteorological cases analyzed are about 2.3 ppm and 5.0 mg/m^3, respectively. These peaks usually occur between 2.5 and 8 km (1.5 and 5 miles) downwind of the burn site. The duration of the exposure depends on windspeed but varies between 2 and 7 min. The hydrogen chloride concentration is significantly less than the suggested STPL's of 4-ppm time-weighted average and 8-ppm peak (table 4-5). The maximum 24-hr aluminum oxide concentration calculated does not exceed 0.024 mg/m^3, which is below the EPA primary and secondary 24-hr average allowable concentrations given in section 4.2.1.1.1.

At the MAF, cleaning and degreasing of component parts with trichloroethylene and spray painting release hydrocarbon emissions in excess of Louisiana air quality standards (ref. 1-8). A solvent loss of about 26.2 kg (37.7 lb) per day occurs, which is in excess of an allowable 6.8 kg (14.9 lb) per day. NASA plans to control these emissions and is currently evaluating the most effective means to do so.

4.2.1.4.2 Transportation of Hardware, Propellants, and Fluids

Ground transportation of Space Shuttle hardware (Orbiter, SRB, External Tank, and propellants and other fluids) to various locations around the country will be accomplished by standard commercial transportation procedures. In all cases, the applicable state and federal regulations on overland and water transportation will be observed. The Orbiter vehicle will be transported from the Palmdale Assembly Facility to the DFRC/EAFB by road. The SRM will be transported by rail between the manufacturing facility (Thiokol/Wasatch during the DDT&E phase) and the launchsites. The External Tanks will be transported, four at a time, by oceangoing tug and barge between the MAF and KSC and Port Hueneme, California. After offloading, the External Tanks are towed on wheeled transporter to their storage facilities. Propellants and other fluids are transported by standard means. The air quality impacts of these actions are not greater than any similar commercial transportation activities.

4.2.1.4.3 Orbiter Approach and Landing Tests

The Orbiter vehicle will be test-flown from the NASA/DFRC at EAFB. These flights do not differ from the routine flight research conducted normally at this site. No significant changes to existing air quality conditions are expected.

4.2.1.4.4 Space Shuttle Crew Training Flights

The crew training flights utilize the Space Shuttle training aircraft as described in section 2.3.1.4. The training aircraft is similar in its effect on air quality to other jet aircraft flying today. It meets all mandatory environmental criteria to which it is subject. It is being operated only at installations with existing aircraft operations. Training aircraft operations at these sites represent only minor increases in cumulative emission levels and consequently minor effects on air quality.

4.2.2 Air Quality of the Stratosphere

Since the Space Shuttle engines are burning as the vehicle passes through the stratosphere, its combustion products are introduced directly into the stratosphere. In addition, chlorofluoromethanes used for cleaning Space Shuttle components in preparation for launch may also enter the stratosphere. Thus, the Space Shuttle operations will introduce chemicals into the atmosphere which could reduce the mean level of ozone in the stratosphere. Because the the long residence time of gases in the stratosphere

(several years), such an effect would not be confined just to the Space Shuttle launchsite but would also be distributed over the globe. This effect is not one of the site-specific effects, which are covered in the impact statements for each site; consequently, it is treated in detail in this environmental statement.

4.2.2.1 Stratospheric Ozone

The stratosphere is a region that extends from an altitude of about 16 to 50 km (52 000 to 160 000 ft) at low latitudes and from 8 to 50 km (26 000 to 160 000 ft) at high latitudes. Its position is shown in figure 4-1. In contrast to the lower atmosphere where turbulence and vertical mixing occur, the stratosphere is relatively quiescent. As a consequence, it is particularly susceptible to contamination because pollutants introduced there tend to remain for long periods of time (several years or more). One of the trace constituents of the stratosphere is ozone. Although ozone represents only a few parts per million of gases in the stratosphere, potential threats to this ozone have become a focus of scientific interst and public concern during the past few years (ref. 4-19). Even in its small amount, stratospheric ozone absorbs virtually all of the solar ultraviolet radiation with wavelengths of less than 290 nanometers (nm) and most of it in the biologically harmful 290- to 320-nm wavelength region. This prevents the radiation from reaching the surface of the Earth in quantities which could adversely affect the lives of human beings, plants, and animals. This absorption is mostly responsible for the temperature inversion (temperature increase with increasing altitude) that characterizes the upper stratosphere and produces its quiescent nature. Ozone also absorbs strongly in the infrared part of the spectrum near 9.6-μm wavelength, and this absorption plays a part in maintaining the heat balance of the globe.

Extensive measurements of the total amount of ozone present in the vertical column of the atmosphere above various points on the Earth's surface have been carried out during the past four decades. Such measurements of the total ozone column give results that vary considerably not only with latitude but also with the time of day and the season of the year. These latitudinal, daily, and seasonal changes are relatively large and regular in character, and their origins are generally well understood. In addition to these changes, longer-term, less regular natural fluctuations have been observed in the annual averages.

Figure 4-4, taken from reference 4-19, gives the ozone column for 1934 to 1970 averaged over the Northern Hemisphere. Seasonal changes as shown in the top part of the figure amount to fluctuations of about ± 25 percent. Averaging out the seasonal variations produced the smoother curve shown in the lower part. The smoothed annual values fluctuate in a range of about ± 5 percent. Possible causes of the annual fluctuations include year-to-year variations in stratospheric circulation, atmospheric nuclear explosions of the 1960's, and large volcanic eruptions.

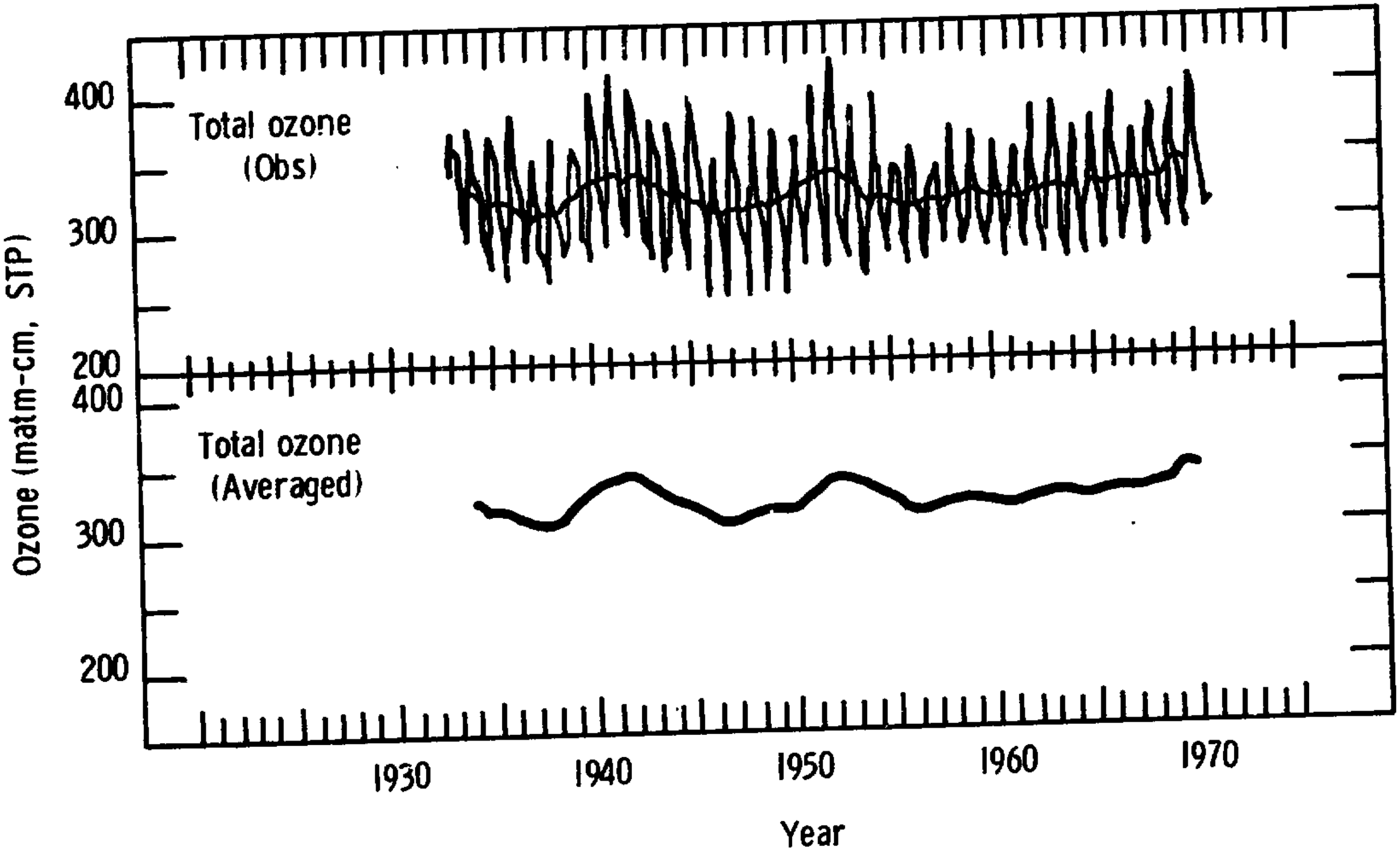

Figure 4-4.-- Long-term variation in total ozone in the Northern Hemisphere.

Concern over manmade effects on the mean level of stratospheric ozone was first raised as a possible consequence of emissions from aircraft flying at high altitudes. The effects of aircraft and other activities of man on stratospheric ozone depend on the natural processes that determine the distribution of ozone in the stratosphere, unperturbed by man. Understanding of those natural processes is extensive and has a firm scientific foundation. The ozone distribution is maintained as the result of a dynamic balance between creation and destruction mechanisms. Ozone is produced in the upper stratosphere by the action of solar ultraviolet radiation upon molecular oxygen and is destroyed by several processes. One of the major processes is a catalytic chain reaction involving various oxides of nitrogen. Other relevant destruction mechanisms include direct reaction of oxygen atoms with ozone and catalytic chain reactions involving chemical radicals containing hydrogen, chlorine, or nitrogen (HO_X, CLO_X, NO_X); see appendix D.

The stratospheric production of ozone is relatively insensitive to human activities. The rate is determined by the intensity of solar radiation on wavelengths shorter than 242 nm and by the distribution in altitude of molecular oxygen and of ozone. The absorption of solar radiation by pollutants can affect the amount and distribution of the ultraviolet light that is available to dissociate oxygen. In this indirect way, pollutants can affect the ozone production, but such secondary effects are small.

The stratospheric destruction of ozone can, however, be influenced by human activities. As mentioned above, several naturally occurring catalytic chemical reactions have been identified as ozone destruction mechanisms. The chemical species involved in these reactions (nitrogen oxide, hydrogen oxide, and chlorine oxide radicals) are referred to as catalysts because they are not used up by the reactions. The individual reactants are regenerated and thereby are capable of reacting with ozone over and over again. Each of them can remove thousands of ozone molecules before being destroyed itself by some other process. Consequently, even though the concentration of these catalytic molecules in the stratosphere is quite low (1 to 10 parts in 10^9), they have important effects.

Artificial introduction of these catalysts into the atmosphere in the amounts now associated with human activities can lead to a significant increase in their stratospheric concentrations. Thus, the average lifetime of an ozone molecule is decreased relative to that in the unperturbed stratosphere. Since the overall production of ozone is not changed and the individual molecules are destroyed more rapidly, the result is a net reduction in the amount of ozone present. One such example of human ability to modify stratospheric ozone is the direct emission of nitrogen oxide into the stratosphere from the exhausts of supersonic aircraft and other aircraft flying at high altitudes. Another example is the release of chlorofluoromethanes. The widespread use of artificial fertilizers may also release nitrogen oxides into the stratosphere, although this potential effect is not yet fully defined.

A recent study (ref. 10-5) indicates that the continued release of chlorofluoromethanes at their 1975 rates will cause an appreciable reduction in the mean amount of stratospheric ozone. In more specific terms, it appears that if their release were to be continued at the 1975 production

rates, ozone would decrease steadily until a probable reduction of about 10.8 to 16.5 percent is reached.

4.2.2.2 Chemical Emissions into the Stratosphere

Two sources of chemical emissions from Space Shuttle operations can be distinguished: One is combustion of the solid rocket propellant during launch. A second, minor source is the release of trichlorotrifluoromethane (Freon-113) during cleaning operations around the launch area.

Combustion of the solid fuel in the Space Shuttle booster engines is the most significant source of chlorine compounds from the Shuttle. The exhaust products emitted during Space Shuttle ascent have been calculated, taking into account nonequilibrium chemistry in the nozzle, plume shocks, and the afterburning region (table 4-2 and ref. 4-3). The total annual stratospheric deposition rates at 60 launches per year resulting from these calculations are as follows.

Species	Annual amount, metric tons
Hydrogen chloride	3584
Chlorine	704
Nitric oxide	18
Carbon monoxide	132
Carbon dioxide	8861
Water	8784
Aluminum oxide	6618

Freon-113 is used to clean and inert the nitrogen tetroxide transfer systems on the launch pad and to clean components of the Space Shuttle system. Freon-113 released in the lower atmosphere eventually reaches the stratosphere, where it interacts with sunlight and ozone, similar to chlorotrifluoromethane (Freon-11) and dichlorodifluoromethane (Freon-12).

At KSC, the amount of Freon-113 needed to replace losses incurred in operations is estimated to be about 1300 metric tons annually for 40 Space Shuttle launches per year. All the lost material must evaporate into the atmosphere. Thus, the total rate of Freon-113 loss to the atmosphere would be about 2225 metric tons per year for 60 Space Shuttle launches per year. (The recovery system planned for Freon-113 is discussed in section 5.3.2).

4.2.2.3 Reduction of Stratospheric Ozone Levels

The effect of the Shuttle exhaust products on the ozone layer was calculated using theoretical models that consider chemical reactions and

transport in the stratosphere. Detailed descriptions of these models and the results of model calculations are provided in appendix D and in references 4-20 and D-4.

The draft environmental impact statement presented results of model calculations for the effect of the Shuttle on the ozone layer, based on models and reaction rates valid in late 1976. However, as noted in the addendum to that statement, an increased value for the rate of the $HO_2 + NO \rightarrow OH + NO_2$ reaction was established in 1977. Preliminary assessments of the effect of this faster rate indicate that there is an increase in the efficiency of the stratospheric chlorine cycle that could increase the predicted ozone depletion due to Space Shuttle operations by a factor of about 2. Calculations of the Shuttle effect have now been completed, using models and reaction rates currently valid, as described in appendix D.

At the maximum launch rate of 60 per year, the Space Shuttle is predicted by these models to reduce mean ozone concentration in the Northern Hemisphere by about 0.25 percent with an uncertainty of about a factor of 2. This is considered to be a maximum estimate, since all the effect is assumed to occur in the Northern Hemisphere. Early calculations using two-dimensional models seem to support this assumption (ref. 4-20), but more recent calculations (ref. D-4) show that transport to the Southern Hemisphere may be fast enough, so that a global average would be more appropriate. This would reduce the predicted effect by a factor of about 2. Further work on two-dimensional model predictions is under way.

Nearly all of the effect of the Shuttle exhaust on the ozone layer is produced by the chlorine compounds in the exhaust. Other exhaust products, such as nitrogen oxides and aluminum oxide particles, were also considered; but they produced ozone reductions predicted to be less than 0.01 percent (ref. 4-20).

A significant difference exists between the effect on the ozone layer due to Space Shuttle exhaust products and chlorofluoromethanes. This difference is the time scale for the two effects. The time required to reach the maximum Space Shuttle ozone reduction is a few years, whereas the chlorofluoromethanes require tens of years. The decay time of the Space Shuttle exhaust effect is correspondingly short, so that after termination of chlorine emissions, the ozone layer would return to normal in a few years. The time scale for the Space Shuttle ozone effect is illustrated in figure 4-5, which shows a plot of predicted ozone reduction as a function of time based on the present mission model. For this case, the total duration of the 0.25-percent ozone reduction level would be about 10 years.

The release of Freon-113 during preparation of the Space Shuttle for launch is estimated to be about 2000 metric tons per year during full-scale operation, assuming that there is no recovery capability. The effect of such a release rate can be estimated from results presented in reference D-4 for Freon-11 and Freon-12. Based on these results, the effect of a continued release of Freon-113 would correspond at the estimated (unrecovered) rate to an end-result reduction of 0.08 percent with a value of 0.04 percent reached in about 50 years, after full-scale Space Shuttle

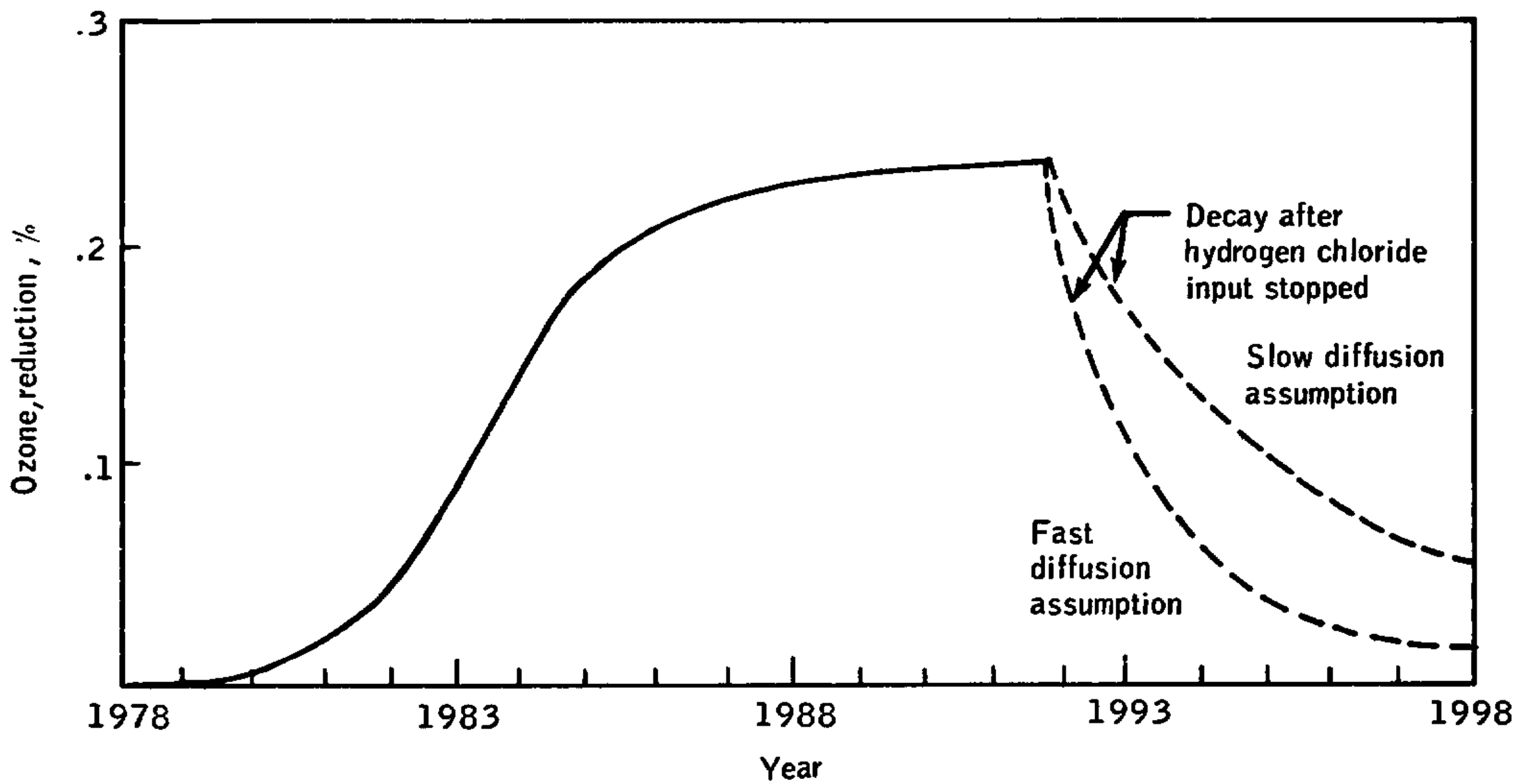

Figure 4-5.- Time scale for the Space Shuttle ozone effect.

operation is initiated. Funding for a system for recovery of the Freon-113 is proposed in the 1979 construction and facilities budget estimates. A discussion of the plans for this recovery is given in section 5.3.2.

4.2.2.4 Environmental Consequences of Space Shuttle Stratospheric Effects

Section 4.2.2.3 and appendix D have outlined the expected effects of Space Shuttle operation on the ozone layer. The potential consequences of these physical effects are to increase the level of stress from solar ultraviolet radiation on ecosystems at the surface of the Earth and to modify the global climate, thus possibly stressing some ecosystems. These effects are evaluated in the following paragraphs.

4.2.2.4.1 Biological Effects of Ozone Reduction

The estimated ozone reduction from full-scale operation of the Space Shuttle is about 0.25 percent. The biological significance of this change is that it results in an increase in the level of biologically harmful ultraviolet (BHUV) radiation that reaches the surface of the Earth.

The BHUV is the weighted sum of wavelengths of solar ultraviolet penetrating the Earth's surface; the weighting factor is the action spectrum for biological damage, such as the deoxyribonucleic acid damage action spectrum or the erythemic action spectrum (ref. 4-21).

For small changes in the ozone level, the percentage increase of BHUV reaching the surface is approximately twice the ozone reduction. The Space Shuttle ozone reduction would then result in a 0.5-percent increase in the BHUV level. The biological effects of this increase can be divided into those which involve plants and animals and those which involve human beings.

o BHUV Radiation Effects on Plants and Animals: The impact on the biosphere of a 0.5-percent increase in BHUV radiation can be assessed from extrapolations of the relatively limited experimental data obtained with high doses of simulated solar BHUV (ref. 4-22). In addition, a more intuitively convincing assessment of the effects of such a BHUV increase can be based on observations made during "nature's experiment": the effects or lack of effects on organisms and ecosystems of exposures to the natural, wide variations in solar BHUV irradiances. The highlights of such an assessment follow.

First, some organisms can be eliminated from concern. Not all organisms in the biosphere are vulnerable to an increase in BHUV radiation. Most animals, including invertebrates, avoid the Sun by living underground or in the shade during at least the heat of the day. The important vulnerable components of the biosphere are human beings, agricultural plants, penned livestock that cannot find shade, and natural terrestrial vegetation.

Second, the effects of a 0.5-percent increase in BHUV radiation on vulnerable organisms will probably not be detectable. The current natural levels of BHUV radiation vary widely because of fluctuations in ozone levels

and passage of clouds. Even in controlled experiments, the responses of organisms to BHUV radiation are highly variable: biological systems are "noisy detectors." Coefficients of variation ranging from 15 to 20 percent are common. Superimposed on the effects of BHUV radiation are the additional effects of other factors to which plants are exposed: temperature, moisture, nutrition, competition, and predation (ref. 4-23). However, lack of detectability of an effect is not equatable with a lack of effect.

If an effect is undetectable, its magnitude can nonetheless be estimated by extrapolation from experiments at high doses, although such estimates are very questionable. Such an analysis of experimental data indicates that an average 0.5-percent increase in BHUV radiation would probably have no effect at all on most plants or ecosystems. It can be demonstrated experimentally that unnaturally high levels of BHUV radiation can be tolerated by many organisms with no significant effect, indicating that organisms have evolved strategies for coping with the BHUV radiation currently irradiating their locality. Many of the mechanisms involved in the strategies for coping have been documented.

a. Behavioral avoidance (e.g., nocturnal behavior or complete avoidance by living underground, deep in the water, or under trees).

b. Screening of critical target molecules by hair, feathers, thick skin, pigment, or nonessential absorbing molecules in cells.

c. Enzymatic systems that repair solar ultraviolet-induced damage in critical molecules or that replace damaged molecules.

d. At the population level, replacement of killed organisms by reproduction of survivors. (This implies that some other factor is rate-limiting for the population size.)

Some organisms need to tolerate only certain peak levels of BHUV radiation for given times of a year because at other times they may be dormant, resistant, or reduced in ecosystem importance. Other organisms (such as trees) may accumulate damage over the entire year and year after year; but many trees, even evergreens, replace their more sensitive elements, their leaves, routinely.

These considerations emphasize the great variability of BHUV radiation doses to which organisms are currently exposed without apparent detrimental effects. It seems reasonable that organisms in a given ecological niche are adapted or adaptable to cope with more BHUV radiation (up to some maximum tolerance level) than they are exposed to on the average. Organisms in nature will likely only show some direct response to an increase in BHUV radiation when it exceeds their maximum tolerance level.

Increased BHUV radiation could have subtle, indirect effects on community structure. If one organism in a particular niche has a slightly greater competitive edge, it will come to predominate; but it will not necessarily eliminate other organisms. A change in some environmental factor such as BHUV radiation may favor a different organism and thus lead to a community structure shift. Such shifts already occur normally and repeatedly in response to the numerous changing and interacting physical

and chemical factors to which the component organisms or an ecosystem are exposed. Such changes are usually not detrimental; ecosystem diversity usually ameliorates detrimental changes. BHUV radiation may be one factor that plays a role in determining community structure, but it is not likely that the influence of a small change like a 0.5-percent increase can be estimated because of the numerous interacting factors.

As with natural ecosystems, agroecosystems are currently subjected to a much wider range of BHUV irradiances than would occur with an increase in BHUV radiance from a 0.25-percent ozone reduction. Extensive studies have shown that given sufficient water by natural means or irrigation, temperature limits the northern extent of growing regions for particular crops (including the number of frost-free days). The factor that primarily limits the southern extent is also temperature: Yields of some plants decrease at lower latitudes partly because of water shortage and partly because of higher respiration rates (and therefore less storage of photosynthate) at the higher summer temperatures.

Preliminary short-term experiments performed in the field and laboratory show that many agricultural plants (15 out of 24 tested), when exposed to very high doses of simulated solar BHUV radiation, showed no significant effect on dry weight productivity (refs. 4-24 and 4-25). If plants showed no response to conditions simulating more than a 40-percent reduction in ozone for the particular area, then it is unlikely that a 0.25-percent ozone reduction will have an effect. In the organisms showing an effect, there was a varying and, in some cases, an inconsistent response to the high BHUV dose. Even in these cases, the response (percentage decrease in dry weight relative to controls) would be an average of less than 0.1 percent for a 0.5-percent increase in BHUV radiation.

o Effects of BHUV Radiation on Human Beings: The most significant potential effect of increased BHUV radiation is increased incidence of human skin cancer (refs. 4-20 and 4-26). The factors supporting an association between nonmelanoma skin cancer incidence and BHUV radiation are as follows.

1. Skin cancers are associated with exposed areas of skin (head, neck, arms, hands).

2. Less skin cancer is found among pigmented races than among Caucasians.

3. Among Caucasians, skin cancer incidence is associated with decreased pigmentation, relative inability to tan, tendency to sunburn, increased exposure to the Sun (e.g., because of an outdoor occupation), and increased intensity (closer to the Equator).

4. Genetic diseases (albinoism, xeroderma pigmentosum) predispose victims to greater skin sensitivity to solar ultraviolet radiation damage and to skin cancer induction.

5. Skin cancer can be produced experimentally in albino and hairless mice and albino rats with ultraviolet radiation.

A 0.25-percent ozone reduction and 0.5-percent increase in BHUV radiation may lead to some increase in the incidence of nonmelanoma skin cancer among susceptible individuals. Such an increase in skin cancer incidence will not be detectable because of the great variability of BHUV and biological responses mentioned previously.

The long latent period (20 to 60 years) for induction of skin tumors and the many other factors that already may be tending to change skin cancer incidence will also prevent detection. Epidemiological data indicate that certain types of skin cancer are already increasing independently of any known changes in BHUV radiation. Such increases may continue. Factors possibly leading to an increased number of cases in the United States include the increased proportion of older people in the population; the changing lifestyle of people, which in recent years involves more leisure time activity in the sunshine; and the net southward migration of the population (between 1940 and 1970, the center of population in the United States moved westward and approximately 56 km (35 miles) south from 39° N latitude; this movement corresponds to about a 1-percent increase in annual dose of BHUV radiation). Improved reporting methods have also probably contributed to an apparent increase in the number of cases. On the other hand, future decreases are also conceivable. Factors possibly leading to a decreased incidence include action based on publicity-induced recognition of the dangers of overexposure to the Sun and more accurate identification of susceptible individuals as a result of research generated by the ozone reduction problem.

In spite of the many unknowns involved in the relationship of BHUV radiation and skin cancer incidence, several groups of investigators have attempted to estimate the possible increase in the number of skin cancer cases that might result from an ozone reduction (refs. 4-26 and 4-27). These investigators have proposed a variety of mathematical models that attempt to fit the epidemiological data. For these models, amplification factors (percentage increase in skin cancer incidence per percentage decrease in ozone) have been derived. Amplification factors from 0.7 to 5 have been reported. The amplification factors emerging from these mathematical models are sensitive to underlying assumptions and the quality of the basic epidemiological data. It is difficult to apply these models to the case of Space Shuttle ozone reduction for two reasons. One is the large uncertainties in the basic epidemiological data, which make predictions of very small effects, such as the Shuttle effect, subject to very considerable errors. Another reason is that all the models implicitly assume that equilibrium has been reached -- i.e., that the ozone decrease has lasted over the course of an average human lifetime (say 50 to 75 years), whereas the duration of the Space Shuttle effect may be significantly less.

This environmental impact statement is based on the current mission model, which extends to 1992. Since the ozone layer would recover in a few years after cessation of input of chlorine containing exhaust products, the time period of ozone reduction could be significantly less than the usual latency period for skin cancer of 40 to 50 years. As a result, the actual effect of the Space Shuttle on skin cancer incidence would be substantially smaller than the estimates provided from existing models.

For the reasons cited in the preceding paragraphs, no specific number of cases can be predicted. If any increase does occur, it must be small relative to the current estimated U.S. incidence of about 300 000 cases per year (ref. 4-27) and consequently will not be detectable against the annual statistical fluctuations of the reported cases.

It should be noted that these considerations refer to nonmelanoma skin cancer, which is rarely fatal and which accounts for more than 97 percent of the total cases. The more serious form of skin cancer, melanoma, is much less clearly correlatable with BHUV radiation. The evidence which supports a correlation has been summarized in reference 4-26. It is not possible at the present time to predict with confidence whether or not a small increase in BHUV radiation will lead to any change in melanoma incidence.

4.2.2.4.2 Climatic Effects of Shuttle Exhaust Deposition in the Stratosphere

The Space Shuttle exhaust products can change the total amount of ozone in the stratosphere and may leave a residue of aluminum oxide particles suspended in the stratosphere. Both factors could alter the radiative energy balance of the Earth, which could lead to global temperature changes.

Indirect effects can arise from the reduction of total ozone by Space Shuttle exhaust. When ozone is removed, more ultraviolet and visible radiation reaches the ground, tending to warm the lower atmosphere and the Earth's surface. At the same time, the loss of ultraviolet absorption by ozone in the stratosphere reduces heating there. Consequently, less thermal radiation is emitted by ozone (particularly in the 9.6-μm absorption band of ozone), cooling the lower atmosphere and the Earth's surface. The two effects compete against one another and result in a reduced net influence on the climate of the lower atmosphere. Because the changes depend not only on the total ozone, but also on the spatial redistributions of ozone, quantitative evaluation of the effect is not yet possible (ref. 4-19). It is probably not a major effect because the large daily and seasonal fluctuations of ozone, ranging from ±20 to ±30 percent, are not generally considered to drive tropospheric temperature changes.

Aluminum oxide particles from the exhaust can remain suspended in the stratosphere for long periods of time. These particles could produce either a warming or cooling effect, depending on their size distribution and optical properties. A detailed calculation of the effect has been performed (ref. 4-28), resulting in an average albedo change of 0.0000004 for a traffic level of one Space Shuttle flight per week and in a mean temperature decrease of 0.000015 K for the Northern Hemisphere. The corresponding numbers for the Southern Hemisphere are 0.43 as large.

The global temperature change is much smaller than global temperature changes believed to have significant effects on climate (refs. 4-27 and 4-28). The effect of the Space Shuttle on global climate is too small to be predicted at the current state of meteorology.

4.2.3 Air Quality of the Mesosphere

Burnout of the SRM's occurs in the stratosphere at 44 km (139 000 ft). However, the main engines of the Space Shuttle continue to burn during passage of the Space Shuttle through the mesosphere (50 to 80 km, or 164 000 to 264 000 ft). The combustion product from the main engine is water vapor, approximately 40 metric tons (88 200 lb) of which are deposited in the mesosphere each launch. The global amount of mesospheric water is about 10^7 metric tons (2.2×10^{10} lb). Space Shuttle input is very small compared to this amount. Local water concentrations will be higher than ambient after Space Shuttle has passed, but no environmental effects have been identified.

During reentry of the Orbiter, a large fraction of the Orbiter's kinetic energy is dissipated in the mesosphere, along a track near a 70-km (231 000-ft) altitude, which extends about a fourth of the way around the Earth. In the shock-heated wake of the Orbiter, atmospheric nitrogen and oxygen are converted to nitric oxide, which could influence the D-layer of the ionosphere and diffuse into the stratosphere to decompose ozone.

The amount of nitric oxide produced during each reentry is estimated to be about 9 metric tons (19 800 lb) distributed along a path 10^4 km (6.2×10^3 miles) long (ref. 4-29). At the peak traffic level of 60 launches per year, 540 metric tons (188 450 lb) of nitric oxide will be introduced into the mesosphere annually. The natural production of nitric oxide is estimated to be about 10^5 metric tons (2.2×10^8 lb) per year. In constrast to the natural production of nitric oxide, the reentry production is highly localized along the trajectory. The time dependence of this local disturbance is such that it disappears in a few days (see ref. 4-29) so that there is no possibility of a localized buildup of nitric oxide at the planned maximum launch rate (refs. 4-29 and 4-30). The downward diffusion of reentry nitric oxide from the mesosphere into the stratosphere (where it could act as a catalyst for ozone reduction) must be a factor of about 5×10^3 smaller than the downward flow of naturally produced nitric oxide, so that its influence on stratospheric ozone must be correspondingly small (ref. 4-30).

4.2.4 Air Quality of the Ionosphere

The ionosphere is the region of the atmosphere above 80 km (258 000 ft), where the concentration of electrons and gaseous positive ions becomes significant. Exhaust products from the Space Shuttle engines can react with ambient electrons and ions, thus reducing the concentration of these particles. This change has the potential for affecting forms of radio communication which interact with the ionosphere, such as short-wave broadcasting.

The effects anticipated from vehicle exhaust emissions in the ionosphere are the same as those experienced with past launches of large rockets. Ionospheric sounders located at Cape Canaveral and Grand Bahama Island obtained records of ionospheric disturbances coincident with the launch of Vanguard II on February 17, 1959, at about 1100 eastern standard time. The data were interpreted as a hole (reduction of electrons and ions) in the ionospheric F-region, the region above 160 km (528 000 ft), produced by the missile's exhaust gas (refs. 4-31 and 4-32).

A similar effect was observed as a result of Faraday rotation measurements obtained at the time of the third-stage burn of a Scout rocket (NASA ST-7/P-21). The effect has been interpreted as an apparent ionospheric electron density reduction in the wake of the rocket's exhaust (ref. 4-33).

More recently, a dramatic decrease in the ionospheric total electron content (column density) coincident with the launch of the Skylab workshop on May 14, 1973, was reported (refs. 4-34 and 4-35). The decrease was believed to be produced by exceptionally increased chemical loss rates caused by molecular hydrogen and water vapor in the exhaust plume of the second-stage (S-II) engine.

The observed effects of rocket exhaust have been confined to the F-region of the ionosphere above a 160-km (528 000-ft) altitude. Analysis of ion-molecule reaction rates involving rocket exhaust products has suggested that their effects on the F-layer of the ionosphere can be traced to rapid charge-exchange reactions with ambient atomic oxygen ions (the dominant positive ions above 160 km). The initial charge-exchange reaction, such as

$$H_2O + O^+ \rightarrow H_2O^+ + O$$

is followed by a rapid recombination step:

$$H_2O^+ + e \rightarrow OH + H$$

Similar fast reactions occur for carbon dioxide and hydrogen. The net result of these reactions is a decrease in the electron concentration of the F_2 ionosphere. At lower altitudes where the dominant positive ions are NO^+ and O_2^+, this process is not effective; accordingly, the Space Shuttle exhaust is not expected to affect the ionosphere greatly.

In the sections which follow, quantitative estimates are given for inputs of Space Shuttle exhaust and reentry gases into the ionosphere, the resulting changes in the ionosphere, and the expected consequences.

4.2.4.1 Exhaust Products Released in the Ionosphere

The Space Shuttle's SRM burns only to an altitude of 43 km (142 000 ft), well below the ionosphere. The liquid propellant engines continue burning to about 111 km (366 000 ft) for a nominal mission. On one mission type (Mission 3B) planned for satellite retrieval, the liquid propellant engines burn to a maximum altitude of 178 km (587 000 ft). Because this is mostly below the F-layer, the exhaust products of the main liquid propellant engines will produce no measurable effect on the ionosphere.

The OMS is a small propulsion unit used by the Orbiter for maneuvering above 278 km (917 000 ft), well inside the F-layer. This engine burns MMH and nitrogen tetroxide at a rate of 18.1 kg/sec (28.8 lb/sec), with a total mass available of 1.1×10^4 kg (2.4×10^4 lb). The combustion products by mass are 26.1 percent water; 40.6 percent nitrogen; 1.4 percent hydrogen; and 31.9 percent carbon dioxide. Thus, polyatomic molecules which

can accelerate the loss rates of ions and electrons compose 59.4 percent of the exhaust products from the OMS engine.

4.2.4.2 Ionospheric Changes Produced by Space Shuttle Exhaust

The products from the OMS exhaust are expected to affect the F_2 layer of the ionosphere. A computer model of the ionosphere was used to assess the magnitude of the effect. A model which simulates chemical releases in the ionosphere is described in reference 4-36. This model was used to simulate the burn of a Space Shuttle OMS. A point release of 10^4 kg (2.2×10^4 lb) of water at 260 km (858 000 ft) was assumed. The release was assumed to be made in the winter at 28.2° south latitude at 1420 hours local time. Results are given in figures 4-6 and 4-7. Figure 4-6 shows the overhead column content of electrons versus local time. Figure 4-7 compares the electron concentration profile before the release and 15 min after it; i.e., at the time of maximum column reduction. The ionosphere is not significantly perturbed below 180 km (594 000 ft). However, the electron concentration decreases as much as a factor of 10 in the region above 180 km.

General conclusions that can be drawn from these calculations are as follows: The Space Shuttle OMS firings will have no effect on the ionosphere below 180 km during daytime. Above this altitude (the F_2 layer), significant decreases in electron concentration will occur and may last for many hours. The location and duration of the effect will vary considerably, depending on the geographic location and altitude of the OMS burn.

4.2.4.3 Results of Ionospheric Changes Induced by Space Shuttle Exhaust

The changes in the F_2 region of the ionosphere expected from the OMS burn may enhance the airglow and alter radio wave propagation. The airglow enhancement will probably be observable only by suitable instruments.

Radio wave propagation effects may include ability to perform radio astronomical measurements at low frequencies, enhanced radio scintillation effects, and changes in the efficiency of radio communications at low frequencies. These effects will be localized along the orbital track and will not persist for more than a day after the OMS burn.

4.3 Water Quality

The effect of the Space Shuttle Program on water quality during the construction and operation of support and manufacturing activities; transportation of hardware and propellants; and the performance of engine tests, crew flight training, and launch operations is covered in the specific environmental statements for each of the sites (refs. 1-2 to 1-9). Standards for water quality in these statements were based on reference 4-37, where appropriate. Highlights of the water quality effects follow.

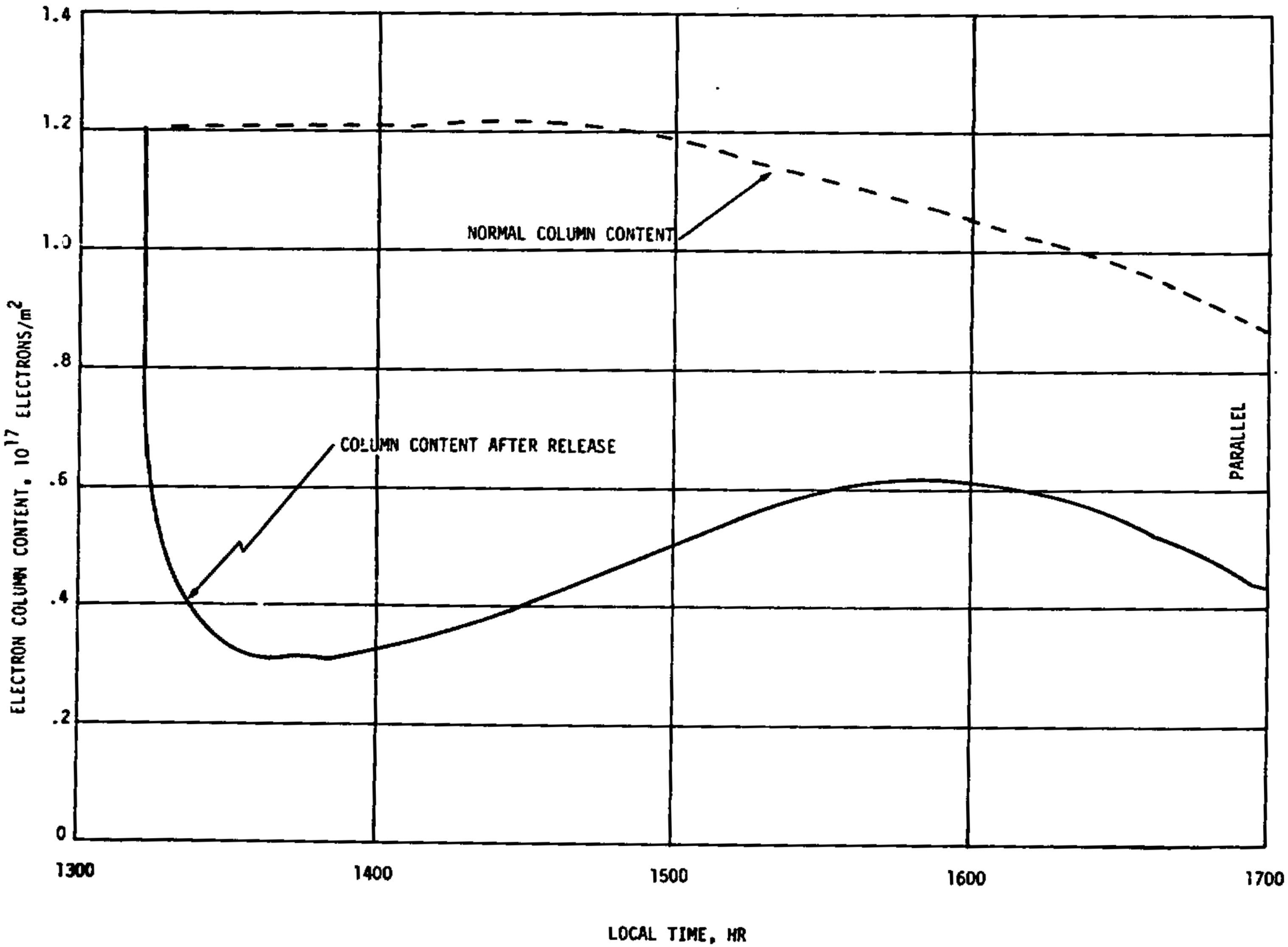

Figure 4-6.-- Time of reduction in total column content of electrons.

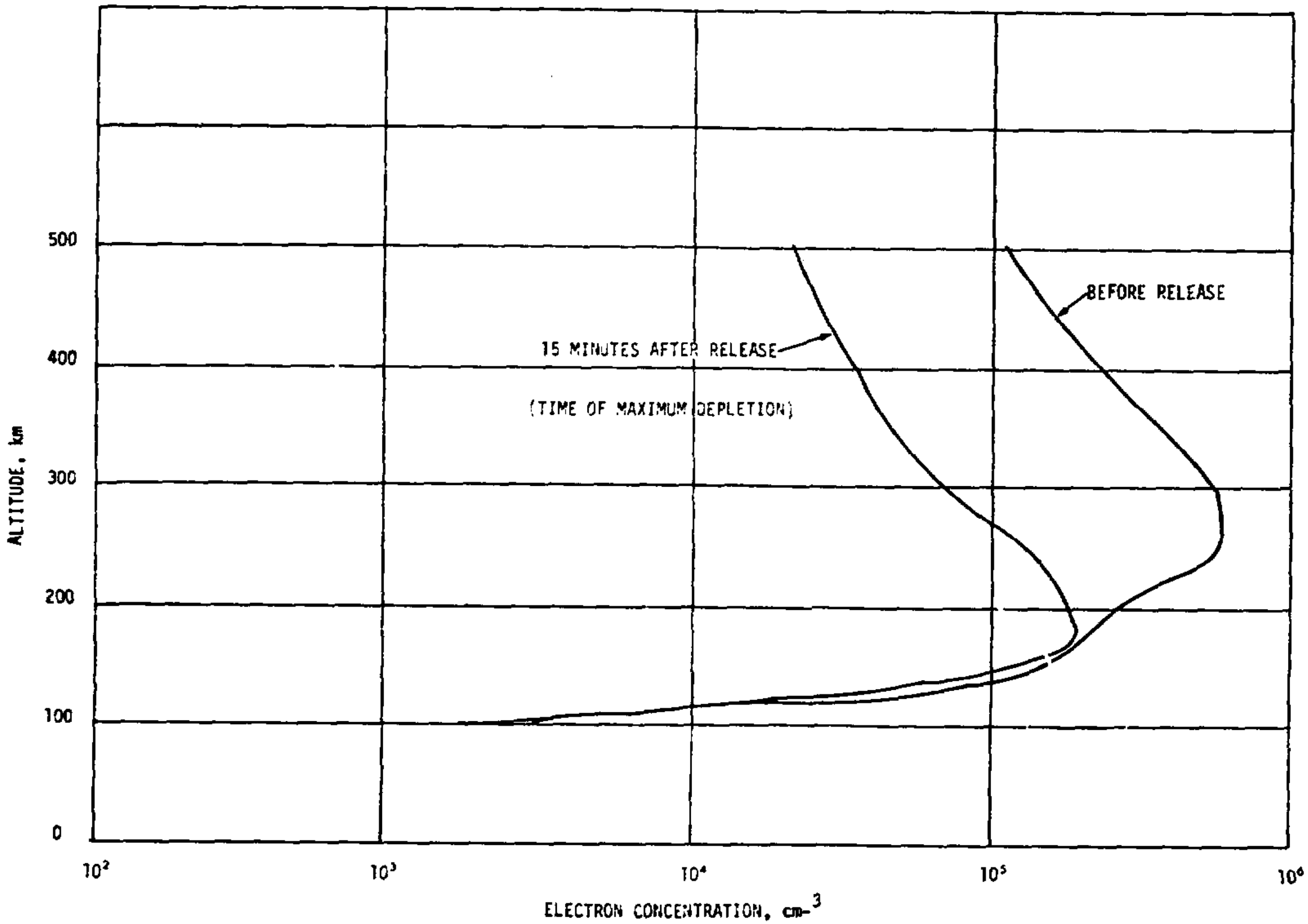

Figure 4-7.-- Comparison of electron concentration profile before release and at time of maximum depletion.

4.3.1 Space Shuttle Launch

At the launchsites, with planned recovery of all Space Shuttle elements except the Orbiter's External Tank, the potential impact of the program on water quality is limited to the following.

- Controlled reentry of the spent SRB and the Orbiter's external tanks.

- Spillage of residual propellant in partial solution with seawater during the spent booster haulout operations.

- Cooling and acoustic damping water interaction with SRB exhaust products.

4.3.1.1 Controlled Reentry of the Solid Rocket Booster and the Orbiter's External Tanks

Jettisoned or reentered hardware will corrode and thus contribute various metal ions to the environment. The rate of corrosion is slow in comparison to the mixing and dilution rate expected in a marine environment; hence, toxic concentrations of metal ions are not expected to be produced. Miscellaneous material (e.g., residual ablator and carbonaceous char) are present in such small quantities that, at worst, only extremely localized and temporary effects would result. Hydrazine fuel and hydraulic fluid in the hydraulic power units and actuators for the SRB thrust vector control system are contained in these components, which are designed to withstand the splashdown loads and salt water environment without leakage.

4.3.1.2 Spillage of Residual Propellant in Partial Solution with Seawater During Haulout of the Solid Rocket Booster

The spent SRB is retrieved at the impact point in the ocean and towed back to the haulout areas or harbors at both the KSC and the VAFB launchsites. Some seawater may mix with or dissolve the unburnt propellant and residue inside the casing (charred insulation and ammonium perchlorate) and may be released during the haulout operations. A worst-case event could involve the spillage of about 79 kg (175 lb) of this material. The maximum allowable concentration (MAC) for fish in water is 50/mg/liter for ammonium perchlorate; see table 4-9 (taken from ref. 4-38). Since both harbors are subject to flushing by tidal action, any contamination is expected to be local and to dissipate rapidly. The ablative coating on the SRB casing will be removed by washing with a water jet at the refurbishing facilities.

Small quantities of fuels and lubricants may also be spilled during harbor activities at KSC and Port Hueneme. As these oils and hydrocarbons are essentially immiscible with water, they may float on the surface. The quantities involved are expected to be small, and the effect is expected to be local.

TABLE 4-9.-- SUGGESTED MAXIMUM ALLOWABLE CONCENTRATIONS (MAC'S) OF PROPELLANTS IN WATER

TABLE 4-9.-- SUGGESTED MAXIMUM ALLOWABLE CONCENTRATIONS (MAC's) OF PROPELLANTS IN WATER

Chemical species	Workroom air threshold limit value,[c] ppm	Observed median lethal threshold or median lethal dose, mg/liter (d)						Suggested MAC
		Chlorella pyrenoidasa	*Daphnia pulex, magna*	*Palaemonetes vulgaris*	Decapoda	Bony fish[f]	Trout	
Hydrazine	0.1	100	1.15	--	--	1.6	--	90.7
MMH	.2	[e]100[e]	[e]30.4	--	--	[e]4.6	--	[h].35
Nitrogen tetroxide[a]	5	--	107	--	--	.63	1.6	[i]95
Ammonium perchlorate[b]	--	781	66	--	--	780	--	50

[a]Based on nitric acid, except the threshold limit value.

[b]Based on nitronium perchlorate.

[c]Taken from reference 4-39.

[d]Taken from reference 4-38.

[e]Values for unsymmetrical dimethylhydrazine.

[f]Lowest observed value for any species.

[g]Concentration causing fingerling trout to lose equilibrium in 24 hr.

[h]Based on threshold limit values for hydrazine and MMH.

[i]Toxic principal devoid of pH effect (i.e., *expected MAC in alkaline or buffered water*).

4.3.1.3 Water Used in Acoustical Damping and Platform Scrubbing

Water is used to suppress acoustic levels in the Orbiter payload bay during the launch process. A total of 1476 m^3/min (390 000 gal/min) is sprayed into the SRB and the Orbiter's main engine flame trenches for about 8-1/2 sec, which is an integrated amount of 221 m^3 (55 250 gal); see reference 4-3. a significant portion of this water will be evaporated and contained in the launch ground cloud. The remainder will undoubtedly contain dissolved hydrogen chloride. Water is also used to scrub and cool the mobile launch platform. Another 1514 m^3/min (400 000 gal/min) is sprayed on the playform's upper surface for about 3-1/2 sec, a total of 93 m^3 (23 330 gal); see reference 4-3. Some of this water is also vaporized, and the residue could contain launch exhaust products. The residual water is led into holding ponds. The water will be treated in the holding ponds to neutralize its acid content before drainage to local water bodies.

4.3.1.4 Potential Water Quality Effects Resulting from Acidic Rain

Acidic rain has been discussed in detail in section 4.2.1.1.2. If acidic rain falls into a body of water, a temporary and localized disturbance at the water surface could result. For large or deep water bodies, dilution is expected to reduce the acidity rapidly.

4.3.2 Space Shuttle Engine Tests

Space Shuttle tests concerned with the main engine (liquid oxygen and liquid hydrogen) at the Santa Susana facility and at the NSTL produce only water vapor and free hydrogen from the combustion process. Water quality is not impacted at these sites. The SRM tests at the Thiokol/Wasatch plantsite will produce exhaust clouds which under normal circumstances will rise and disperse without affecting water quality. The OMS and RCS test firings are conducted at the White Sands Test Facility. Waste liquids from all areas are neutralized before release to the drainage systems. The underground water table is approximately 122 m (400 ft) below grade, and the nearest stream is the Rio Grande 24 km (15 miles) away. The main engines will also be tested on the pad at the KSC launchsite on one occasion. Water will be used for acoustic damping and launch platform cooling. The effects will be much less than those of a normal launch involving liquid-fueled rockets.

4.3.3 Activities at the Manufacturing and Test Facilities

The discharge of waste water at the manufacturing and test facilities, both during construction and in operation, will comply with local, state, and federal regulations. The activities involved are the construction of the Orbiter at the North American industrial plant (Downey, California), final assembly and checkout of the Orbiter at the North American facility (Palmdale, California), construction of the External Tank at NASA/MAF (New Orleans, Louisiana), and SRM processing at the Thiokol/Wasatch plant (Promontory, Utah). Activities which could conceivably contribute to changes in water quality are disposal of waste propellant, spent SRM case washout, and

normal SRM processing. The approximate amount of material remaining at the surface of the burn area as a result of all anticipated SRM DDT&E burning activities is estimated at 190 kg (400 lb). During SRM case refurbishment, water will be used to remove charred insulation from fired segments. Sludge is removed from the waste water and disposed in a sanitary landfill; the waste water is deposited in a percolation/evaporation catch basin. No changes in the quality of surface or ground water are expected in SRM processing or any other activities in connection with manufacturing and test.

4.3.4 Transportation of Hardware, Propellants, and Fluids

Ground transportation of the various components of the Space Shuttle to the assembly points will be accomplished by standard commercial transportation means. In all cases, the applicable local, state, and federal regulations on overland and water transportation will be observed. No effects to water quality are expected from normal transport operations.

4.3.5 Orbiter Approach and Landing Tests

The Orbiter has been test flown from NASA/DFRC at EAFB, California. These flights do not differ from the routine flight research conducted normally at this site. No effects to water quality are expected from normal operations.

4.3.6 Space Shuttle Crew Training Flights

Crew training flights utilize the Space Shuttle's training aircraft, which are modified Grumman Gulfstream II, subsonic, twin-engine turbofan aircraft. They are based at Ellington Air Force Base, Texas; and training flights are conducted at the Northrop Strip of the White Sands Test Facility, New Mexico. The water quality effects of training aircraft operations do not differ from the routine flight activities normally conducted at these sites.

4.4 Noise

Acoustic noise (as differentiated from sonic boom, which is treated separately) is generated in many different aspects of the Space Shuttle Program. The major noise effects in the program are generated by rocket engine testing and launch. In the paragraphs that follow, the various noise sources are cataloged and evaluated briefly, with emphasis on the major noise effects.

4.4.1 Space Shuttle Launch

The lift-off thrust of the Space Shuttle is 30.7×10^6 N (6.9×10^6 lb), slightly less than that of the Saturn V, which had a lift-off thrust of

33.4×10^6 N (7.5×10^6 lb). Since rocket engine sound levels are approximately correlated with thrust, it appears that the Space Shuttle launch will produce about the same sound levels as the Saturn-V launch.

Measurements of lift-off noise were taken during the Saturn-V launches, and the results have been used to derive equations to predict noise from Space Shuttle lift-off (ref. 1-5). The calculated maximum sound pressure level contours at ground level for Space Shuttle launch are shown in figure 4-8.

The distribution of sound level frequency for vehicle altitudes up to 10 700 m (35 000 ft) is shown in figure 4-9. The sound pressure drops about 10 dB (an order of magnitude in intensity) when the vehicle reaches an altitude of 10 700 m (35 000 ft), 60 sec after lift-off. The nominal duration of intense launch noise is consequently taken to be about 1 min. To evaluate the effect of this sound level on human beings, it is necessary to convert the absolute sound pressure to an A-weighted sound pressure level in which the sound level is weighted by the relative sensitivity of the human ear to sound of various frequencies (ref. 4-40). A further step is the calculation of a relatively new noise descriptor, the "equivalent A-weighted sound level" (Leq). The equivalent A-weighted sound level is the constant sound level that conveys the same A-weighted sound energy as the actual time-varying A-weighted sound (ref. 4-40).

The maximum sound pressure level is seen in figure 4-9 to occur at a frequency of about 20 Hz. The application of the A-weighted scale to this frequency distribution results in a reduction factor of about 30 dB for conversion from absolute sound pressure levels to (A) sound pressure levels.

From the contours shown in figure 4-8, the absolute sound pressure level 6 km (3.7 miles) from the launchsite (approximate distance of the KSC viewing stand) is predicted to be 123 dB, corresponding to an A-weighted level of 95 dB(A). Assuming the duration of the sound to be 1 min, the 24-hr weighted average sound level (Leq) is 65 dB(A) for a 60-dB(A) background noise level. This is below the 70dB(A) daytime guideline set by the EPA, but it would exceed the suggested 60-dB(A) nighttime noise limit.

The nearest mainland area from the KSC launchsite is 17 km (11 miles) distant. At this point, the sound pressure level is down to 110 dB or about 80 dB(A), corresponding to an Leq of about 60.1 dB(A) for a 60-dB(A) background noise. Similar considerations apply to VAFB, where the sound pressure level at the nearest-to-pad private property line is 120 dB, or about 90 dB(A), corresponding to an Leq of 62 dB(A), assuming a 60-dB(A) background and 1-min duration.

4.4.2 Engine Tests

Thrust for Space Shuttle launch is provided by the Space Shuttle's main engine and the SRB. In addition to these large rocket engines, smaller ones are used for orbital maneuvering, attitude control, and stage separation. Smaller engines are tested in existing government and contractor facilities as part of a series of small engine tests that have

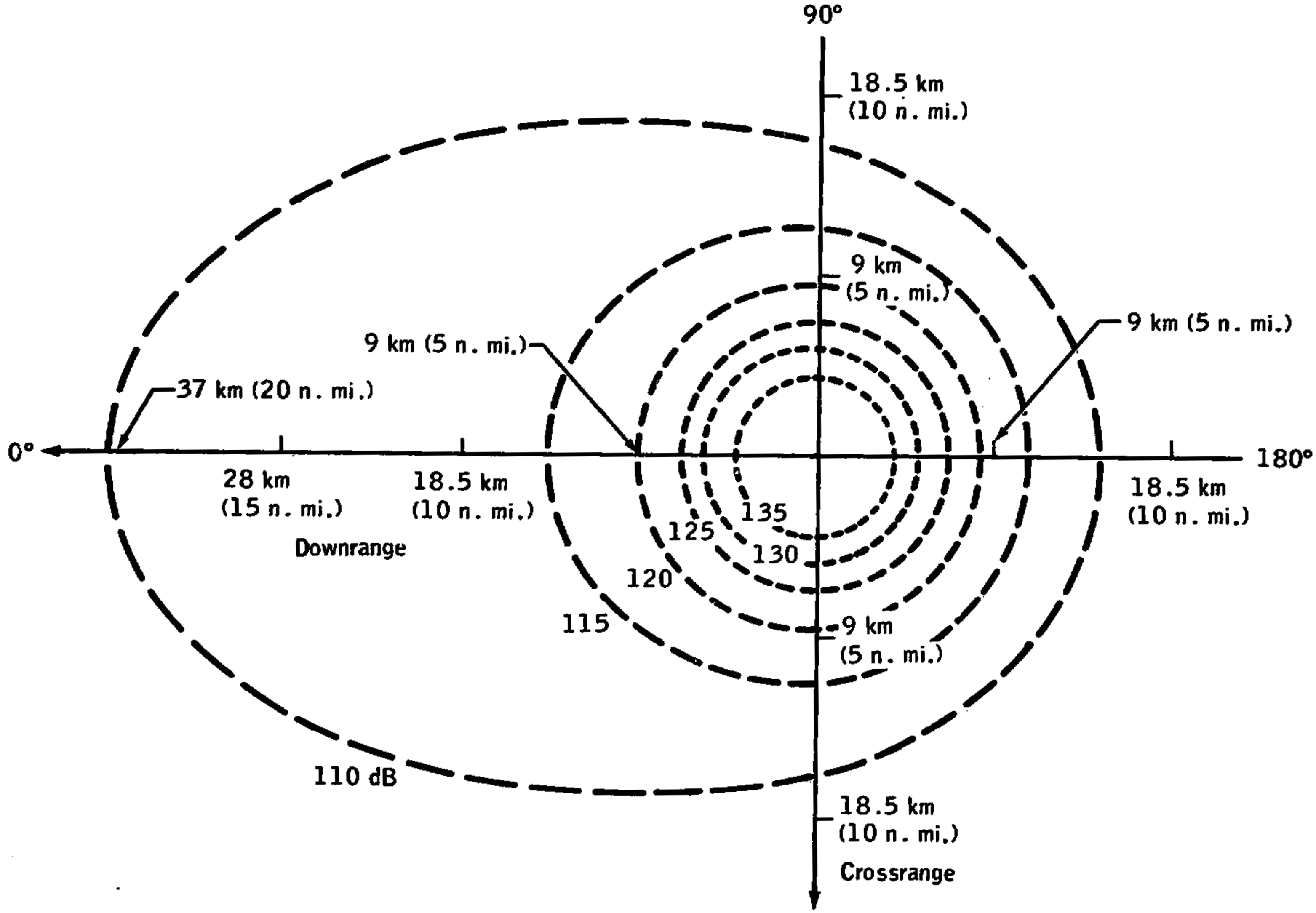

Figure 4-8.-- Calculated maximum sound pressure level contours at ground level for a Shuttle launch. (Taken from ref. 4-1.)

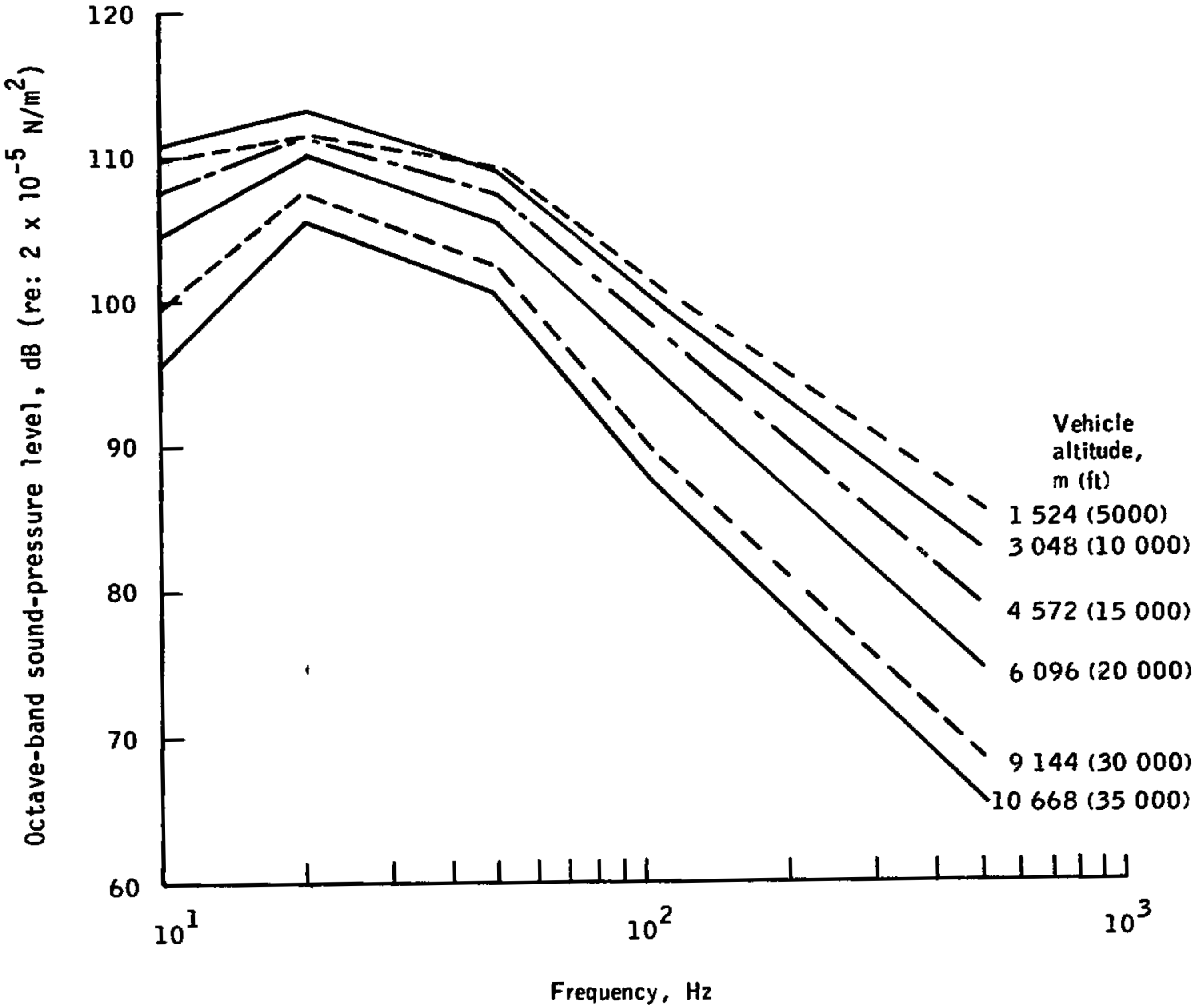

Figure 4-9.-- Distribution of sound level with frequency for Shuttle at altitudes of up to 10 668 m. (Taken from ref. 4-1.)

been going on for a number of years. These tests do not represent a significant change or increase in the general noise pattern of the affected areas as discussed in the site-specific statements.

Tests of the main engine and the SRB produce significant noise levels. The nature of the noise from these tests can be described as being intense, relatively short (1 to 4 min), composed predominantly of low frequencies, and infrequent (several weeks apart). Since low frequencies predominate, the sound is less harmful to human hearing than if moderate to high frequencies predominated.

4.4.2.1 Test Firings of the Main Engine

The main propulsion system for the Space Shuttle consists of three liquid hydrogen/oxygen engines, each with a nominal sea-level thrust of 1 688 100 N (357 000 lb). The individual engine tests are conducted at Santa Susana, California. Environmental effects are discussed in the environmental statement for that site (see ref. 1-2). Tests of the cluster of three engines are to be performed at the NSTL, and an on-pad test is planned at KSC.

The NSTL site was designed for testing large rocket engines; consequently, it has a large buffer zone around the test stand. The sound pressure level contours around the test site have been calculated for the main engine tests (ref. 1-4), and the tests show that the maximum sound pressure level at the border of the buffer zone is approximately 104 dB for standard atmospheric conditions.

The maximum sound pressure level of 104 dB at the border of the NSTL buffer zone corresponds approximately to an A-weighted sound level of 85 dB(A). This corresponds to a 24-hr average sound level, Leq, of 63 dB(A), assuming a 4-min test and a 60-dB(A) background noise level. This level is well below the Leq = 70 dB(A) guideline from the EPA (ref. 4-40).

Minor structural damage from low-frequency sound is another possible environmental effect of the test noise. This test site has been used previously for many tests of large rocket engines, most recently the S-II and S-IC engines. A few household-type damage claims resulted from these tests (ref. 1-4).

4.4.2.2 Test Firings of the Solid Rocket Motor

The SRM has an initial sea-level thrust of 11.6×10^6 N (2.6×10^6 lb), and duration of the burn is 122 sec. The noise generated by SRM test firings is locally intense, has predominantly low frequencies, lasts a short time, and will occur infrequently (seven times over a period of 18 months during the development). The time between firings will typically be 2 months. The A-weighted sound pressure contours for firings at the Promontory, Utah, site have been calculated; they show that the maximum sound level to which the public might be exposed in terms of the A-weighted sound level is 95 dB(A) on State Route 83 (see ref. 1-6). The Leq corresponding to this sound level (for a 2-min test) is 67 dB(A), assuming a background noise level of 60-dB(A).

This value is less than the daytime 70-dB(A) limit suggested by the EPA (ref. 4-40). Measured values have been significantly less than calculated values, showing the calculations to be conservative. Only 80- to 83-dB(A) sound levels were measured at State Route 83 during tests in 1977.

Although no direct noise-related health effects will result from the SRM engine testing, large areas will be subjected to overall sound pressures of 100 dB or more, predominantly of low frequencies. As in the case of the NSTL, vibrations of windows and rattling of dishes may occur.

4.4.3 *Crew Training Flights and Approach and Landing Tests*

Two modified Gulfstream-II aircraft will be used for crew training flights. These aircraft meet all mandatory environmental criteria to which they are subject. They will be operated only at installations with existing aircraft operations.

The ALT's are a series of eight Orbiter test flights at the DFRC by which the Orbiter is flown piggyback atop a Boeing 747 aircraft, separated, and flown to a landing. This activity represents a continuation of normal test flight activity at this location. The flights are infrequent (averaging one every 2 months) and will be completed in early 1978.

4.4.4 *Transportation of Hardware*

Most of the Space Shuttle components are shipped to test and assembly points by rail, truck, canal, and air routes, using conventional commercial procedures. Exceptions to this are the piggyback air transport of the Orbiter (the Orbiter is mounted externally on a Boeing 747 aircraft), ground transport of the Orbiter from Palmdale to the DFRC, the ground transport of the Orbiter at MSFC, and the movement of major Space Shuttle components around the launch complexes at KSC and VAFB using a ground transporter.

The first six launches of the Space Shuttle will be from KSC. The first four landings of the Orbiter will be at DFRC. The Orbiter will then be flown piggyback to KSC for refurbishment and launch. In later flights, the Orbiter will land and be refurbished at KSC. These Boeing 747 flights do not represent a significant addition to overall noise levels around KSC and DFRC.

Ground transport of bulky components, such as the Orbiter, is accomplished by using equipment similar to that used for housemoving. The Orbiter is transported from Palmdale to the DFRC over a special route (ref. 1-3).

4.4.5 *Construction and Modification of Support and Manufacturing Facilities*

Construction and modification of facilities involve the use of noisy, heavy machinery, such as bulldozers. New constructions and modifications at KSC and VAFB are planned for the facilities needed for Space Shuttle flight operations. Most of the facilities needed for Space Shuttle at Santa Susana, California, have already been built. Noise levels from construction and modification of new facilities are not expected to be

unusual; they are discussed in the appropriate site-specific environmental statements.

Facilities which manufacture major components of the Space Shuttle system include the MAF at New Orleans, Louisiana (External Tank); the assembly plant at Palmdale, California (Orbiter); and the Wasatch plant at Promontory, Utan (SRB's). These facilities are located in areas with low population densities, and their operations represent a continuation of activities similar to those carried on in the past.

4.4.6 Summary of Acoustic Noise Effects on the Environment

The various construction, modification, transporation, and small engine testing activities of the Space Shuttle Program do not represent significant changes to the existing noise environment. Testing of the SRM and main engine and launch of the Space Shuttle produce intense, low-frequency sounds of brief duration and infrequent occurrence. The sound levels in regions accessible to the public are below the EPA-suggested standard 24-hr average daytime exposure level of 70 dB(A). The low-frequency sound may cause minor damage to privately owned structures outside the test sites and launchsites, but experience from previous operations indicates that such occurrences will be small and very infrequent.

The effects of noise on animals are of interest because of the endangered species present around both the KSC and VAFB launchsites. Insufficient information is available to evaluate this effect fully, although the available data (ref. 4-41) suggest that for the short-duration infrequent noise considered here, the effects on domestic animals and wildlife will not be significant.

4.5 Sonic Boom

4.5.1 Source and Nature

As any body moves through the air, the air must part to make way for that body and then close itself once the body has passed. In subsonic flight, pressure signals (precursor waves which travel at the speed of sound) move ahead of the body to forewarn of its approach and the parting of the air (the passage of the body is a smooth process). In supersonic flight, precursor waves cannot precede the body; the parting process is abrupt. A bow shock wave parts the air, which expands as it passes around the body; and then a trailing shock wave recompresses the air as it closes behind the body. These waves travel through the atmosphere as pressure waves and, because of the abrupt noise they generate when passing an observer, are called sonic boom. This general pattern of bow shock wave, expansion region, and recompression shock is idealized as the N-wave signature commonly associated with the sonic boom. The phenomenon occurs for all supersonic flight (see fig. 4-10). The duration of the N-wave depends mostly on the size of the object which produces the boom. A medium-sized aircraft such as the SR-71 or the Concorde transport produces a wave lasting about 0.2 sec (see ref. 4-42). The Orbiter will produce waves of similar duration.

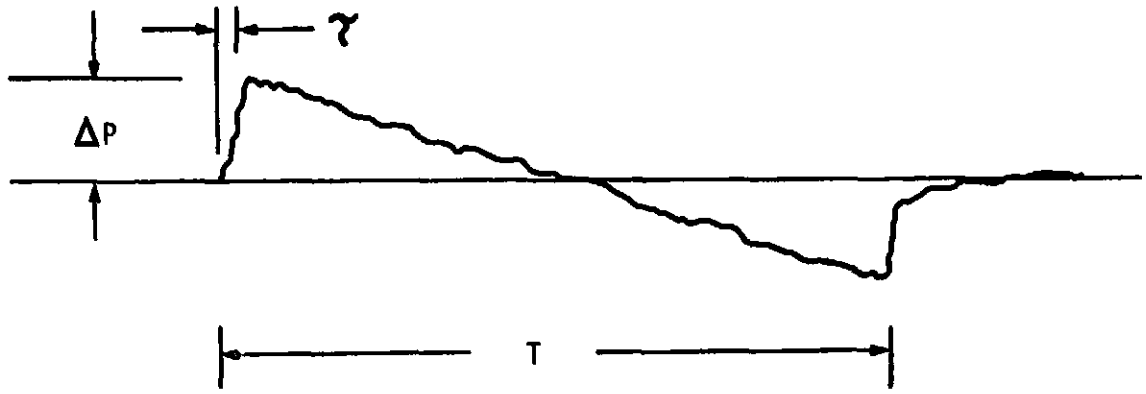

Figure 4-10.-- Classic N-wave (described by four parameters: rise time, τ; overpressure, ΔP; period, T; and impulse under the wave).

The abruptness of the pressure changes is responsible for much of the concern about the sonic boom. It gives it the startling audibility and dynamic characteristics of an explosion; and even at great distances from the vehicle where pressure levels produced are physically harmless, some public complaints are received. Sonic boom is likely to be of concern in Space Shuttle operations because segments of the trajectories followed during ascent and descent involve supersonic flight within the atmosphere.

The characteristics of the shock pattern at its source are influenced by flightpath characteristics (e.g., altitude, speed, angle of attack, flightpath curvature, and accelerations either along or transverse to the flightpath) and body characteristics (e.g., bluntness, weight, exhaust plume, and volume). The pressure signature that reaches the ground is subject to the additional factors of air turbulence, winds, and temperature variations of the atmosphere traversed by the pressure wave in addition to certain flightpath characteristics.

Maneuvers associated with aircraft flight can result in focusing of the shock waves over small areas of the surface where overpressures may be greater than they would be for level flight. Focusing cannot be accurately predicted by theory; however, reference 4-43 presents a method for approximating focal overpressure. Available flight test data for aircraft indicate that the pressures can be as much as two to five times higher in the focal zone than outside. Focusing occurs briefly during the boost phase of Space Shuttle launch.

Extensive knowledge of these factors gained by past studies of conventional supersonic aircraft provides much of the basic information required for prediction of sonic boom pressure patterns (i.e., footprints) of the Space Shuttle. It was necessary, however, to extend this basic knowledge by additional studies and experiments so that it would apply to

the Space Shuttle shape and the extremely high speeds and altitudes at which it operates. These new procedures were successfully tested on sonic booms from an Apollo spacecraft, and predicted and measured booms were in good agreement (ref. 4-44). Preliminary sonic boom calculations for the Space Shuttle are given in reference 4-2.

4.5.2 Ascent

The ascent phase will create the largest sonic booms of the mission; but since only over-water launch azimuths will be used, these booms are not expected to penetrate populated areas. These large booms are the result of two distinct effects. First, the overpressures that will be experienced over the ocean during supersonic ascent will be greater than those that might be expected from the Space Shuttle vehicle alone because of the contribution of the rocket exhaust plume. This plume increases the effective size of the Space Shuttle vehicle, and preliminary indications are that the overpressures may be double those of the vehicle alone. Overpressures as high as about 290 N/m^2 (6 psf) may be expected at downrange locations, where the shock waves first reach the ocean's surface on the groundtrack, approximately 60 km (33 n. mi.) downrange. The sonic boom's intensity diminishes both downrange to 48 N/m^2 (1 psf) at 85 km (51 miles) and laterally on either side of the groundtrack to lateral cutoff down to about 96 N/m^2 (2 psf). Lateral cutoff occurs when the local gradient in the speed of sound causes the ray path to turn to a horizontal orientation (parallel to the ground). No sonic boom disturbance will occur between the launchsite and the shock wave touchdown point. The approximate launch sonic boom footprint for a KSC launch is shown in figure 4-11. A similar pattern is expected for a VAFB launch.

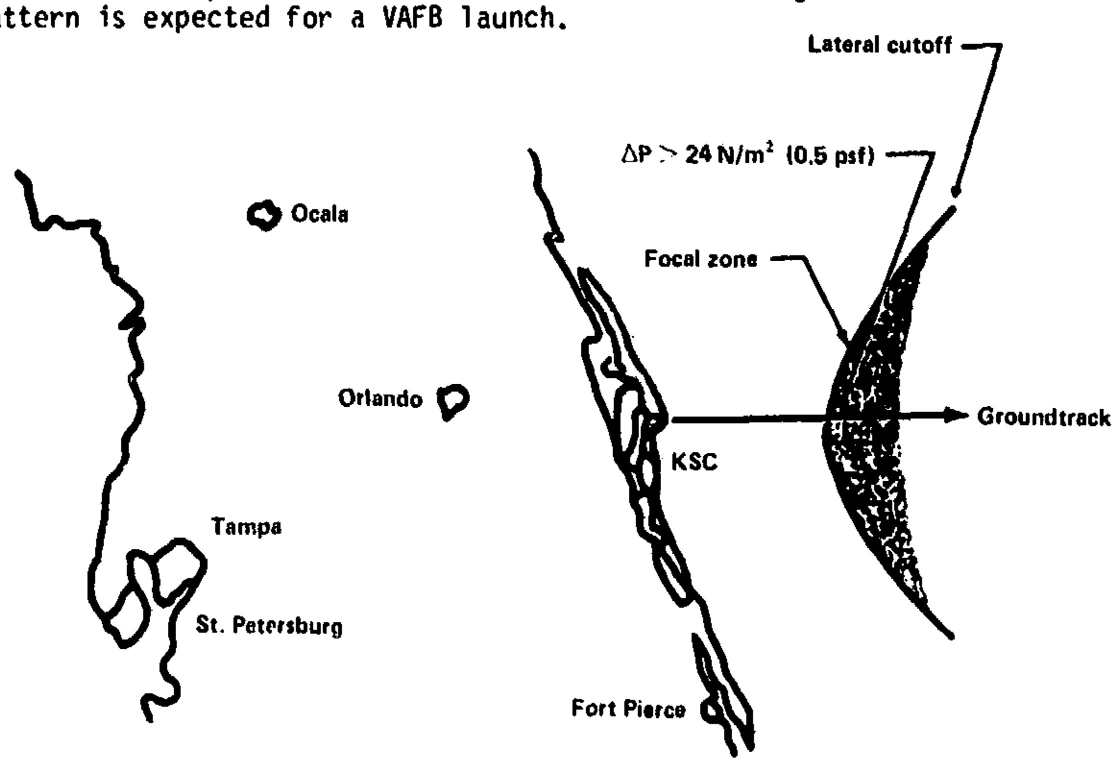

Figure 4-11.-- Estimate of Space Shuttle ascent sonic boom footprint for a launch at Kennedy Space Center.

The second effect is focusing caused by the longitudinal acceleration and pitchover maneuvers necessary for the vehicle to achieve orbit. This results from the accumulation and reinforcement of pressure waves in the focusing region. This region is a narrow area located along the touchdown line out to lateral cutoff about 75 km (40 n. mi.) to either side of the groundtrack.

With maximum overpressure levels as high as about 290 N/m^2 (6 psf) without focusing and with focusing factors ranging from 2 to 5, the possibility of overpressures on the order of 1440 N/m^2 (30 psf) cannot be ruled out at the center of the focal zone and 480 N/m^2 (10 psf) at lateral cutoff. The overpressures in the focal zone will be limited to a very narrow region approximately 300 m (985 ft) wide at the groundtrack and even narrower out near lateral cutoff.

As far as it is now known, this focused ascent boom appears unavoidable; this consideration contributed to the decision to employ a coastal launchsite permitting occurrence of the ascent sonic boom over the ocean in most cases. The location of the focused boom will be predictable based on a given trajectory and existing wind conditions. Range safety designates a launch danger zone for each launch. This is a sea area and air space measured from the launch point and extending downrange along the intended flight azimuth. The size is based on the potential hazard to ships and aircraft. Helicopter and radar surveillance of this zone commences an hour before launch. Should the overpressure levels be considered harmful, the location of the focused boom will be included in the launch danger zone. Ships and aircraft in the area likely to be affected will be warned of impending launches (this is the practice for current launches). Focused sonic booms occur during the supersonic boost phase of all launches, including Apollo launches, but have apparently gone unnoticed because they occurred at sea and are very localized.

Because the launch azimuth used by the Space Shuttle vehicle will place the ascent sonic boom footprint over water, it is expected that for some launches out of VAFB, impingement may occur on the Channel Islands (see section 4.5.5.2). Studies are currently under way to assess the possibility of varying the trajectory associated with this inclination so as to move the focal region away from these islands. For launches out of KSC, there will be no impingement of the sonic boom on land masses.

4.5.3 SRB and External Tank Reentry

After SRB separation, the Orbiter and External Tank continue to climb and the SRB reenters the atmosphere. During descent, the spent booster will generate a sonic boom striking the surface over an area from 280 to 370 km (150 to 200 n. mi.) downrange from the launchsite. In this area, maximum overpressures rise to levels between about 96 and 144 N/m^2 (2 and 3 psf). This area of maximum overpressure coincides with the booster impact area which must be kept under surveillance to effect booster recovery as was done for the Apollo capsule recovery.

The External Tank contains liquid hydrogen and oxygen used by the main engines during ascent. The propellant is expended before orbit, and the

tank falls to the ocean after separating from the Orbiter. A sonic boom is produced on reentry of the External Tank. Maximum overpressures between 96 and 192 N/m^2 (2 and 4 psf) are expected over remote areas of the Indian Ocean for KSC launches and the South Pacific Ocean for VAFB launches.

4.5.4 Orbiter Reentry

Reentry of the Orbiter produces a sonic boom over populated areas. Landing of the Orbiter is planned at the DFRC for the first four Space Shuttle flights during 1979 and 1980. The sonic boom footprint predicted for this area is shown in figure 4-12. Landings of the Space Shuttle at KSC are planned to commence in 1980 at a rate of 6 Orbiter landings per year, increasing to 40 per year by 1984. The sonic boom footprint predicted for the Florida peninsula is shown in figure 4-13. Landings at VAFB are expected to start in 1982, increasing to 20 per year by 1984. The sonic boom footprint predicted for this area is shown in figure 4-14.

Inspection of these figures shows that overpressures for the nominal trajectory during Orbiter return will not exceed 24 N/m^2 (0.5 psf) until the vehicle is within 650 km (500 n. mi.) of the landing site. Overpressures of 48 N/m^2 (1 psf) are exceeded at about 185 km (90 n. mi.) from the landing site, and the nominal maximum overpressures for any Orbiter entry will not exceed 101 N/m^2 (2.1 psf). The area which experiences overpressures between 96 N/m^2 (2 psf) and 101 N/m^2 (2.1 psf) is generally small (about 100 sq. mi.) and is located no further than about 44 km (24 n. mi.) from the landing site.

4.5.5 Environmental Effects of Sonic Booms from Space Shuttle Operations

Sonic boom is an impulse noise, defined as a discrete noise of short duration in which the sound pressure level rises very rapidly to a peak level (ref. 4-45). The most important parameters for characterizing impulsive noise are the peak sound pressure level, the effective duration, the rise time, and the number of repeated impulses.

The impulse noise of a sonic boom is not unique. Manmade explosions have many of the characteristics of the normal sonic boom. A natural phenomenon which bears a striking resemblance to sonic booms is the thunder produced by lightning strikes. The overpressure and spectral content of thunder for lightning strikes up to a distance of 1 km (0.6 mile) are almost indistinguishable from those of sonic booms (ref. 4-46).

4.5.5.1 Effects of Sonic Booms on Humans, Buildings, Animals, and Marine Life

Sonic booms tend to be unexpected. Impulsive noises which are novel, unheralded, or unexpectedly loud can startle people and animals. Even very mild impulsive noises can awaken sleepers. Because startle and alerting responses depend very largely upon individual circumstances and psychological factors unrelated to the intensity of the sound, it is difficult to make any generalization about acceptable values in this connection.

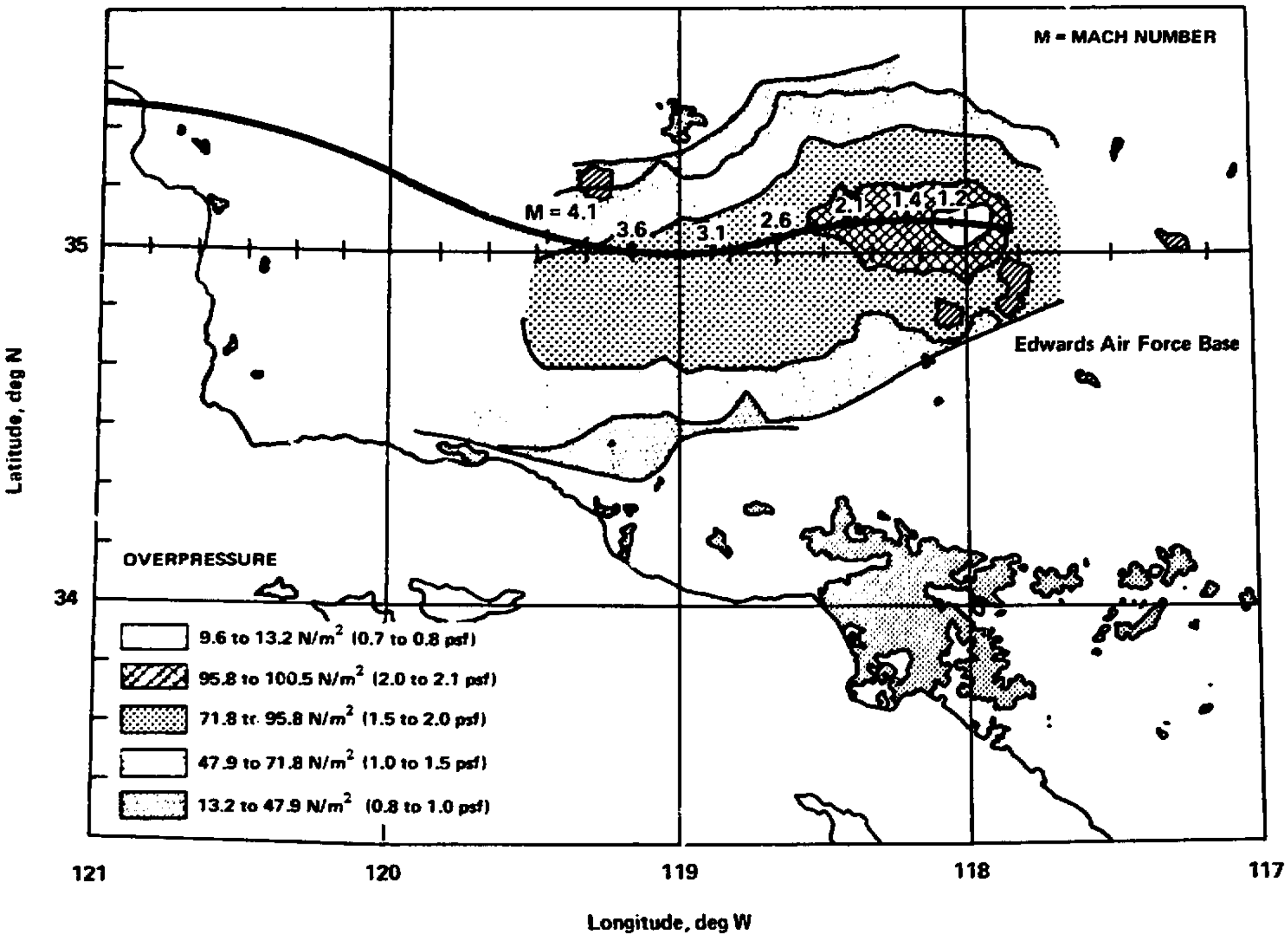

Figure 4-12.-- Sonic boom footprint for the Dryden Flight Research Center.

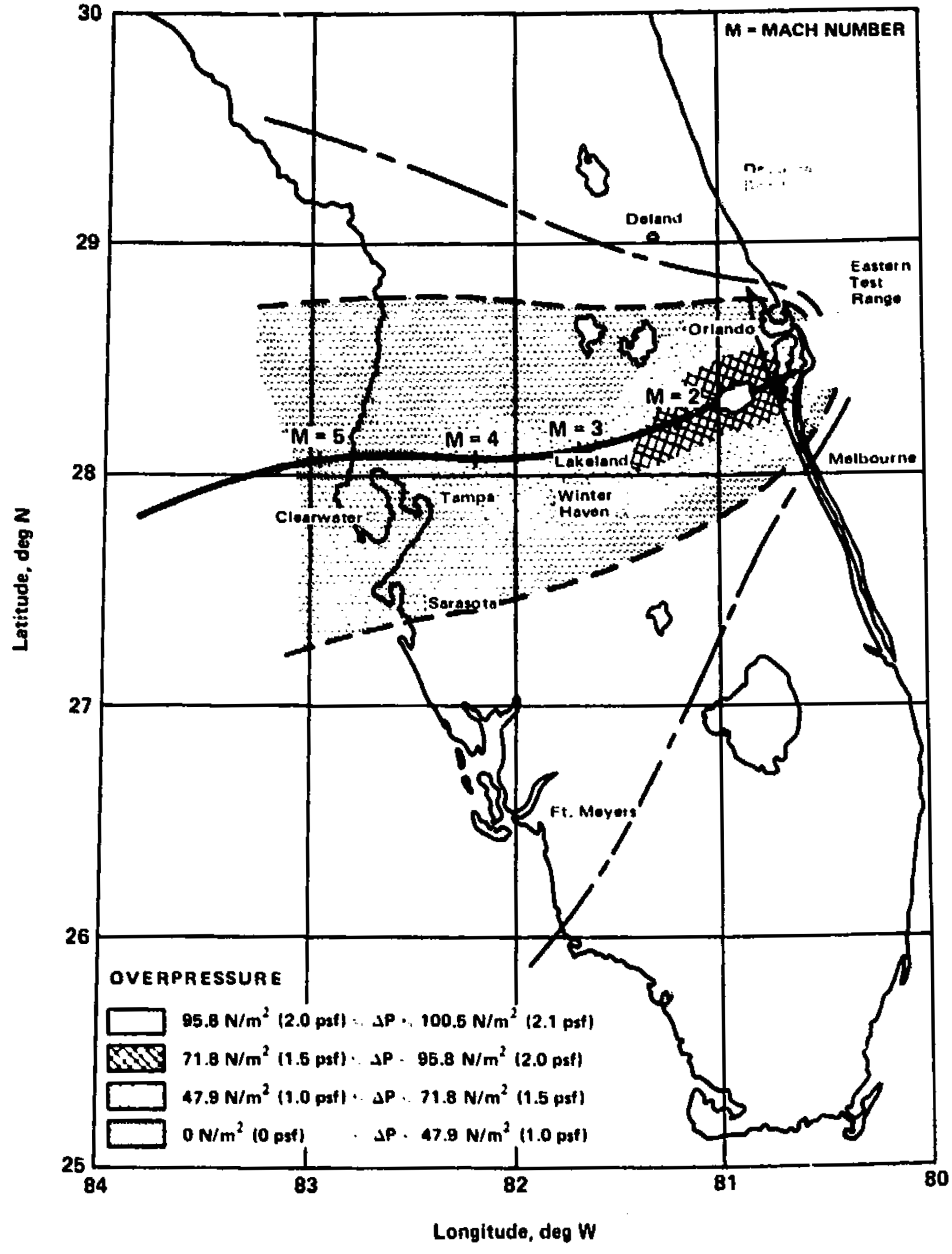

Figure 4-13.-- Sonic boom footprint for the Florida peninsula.

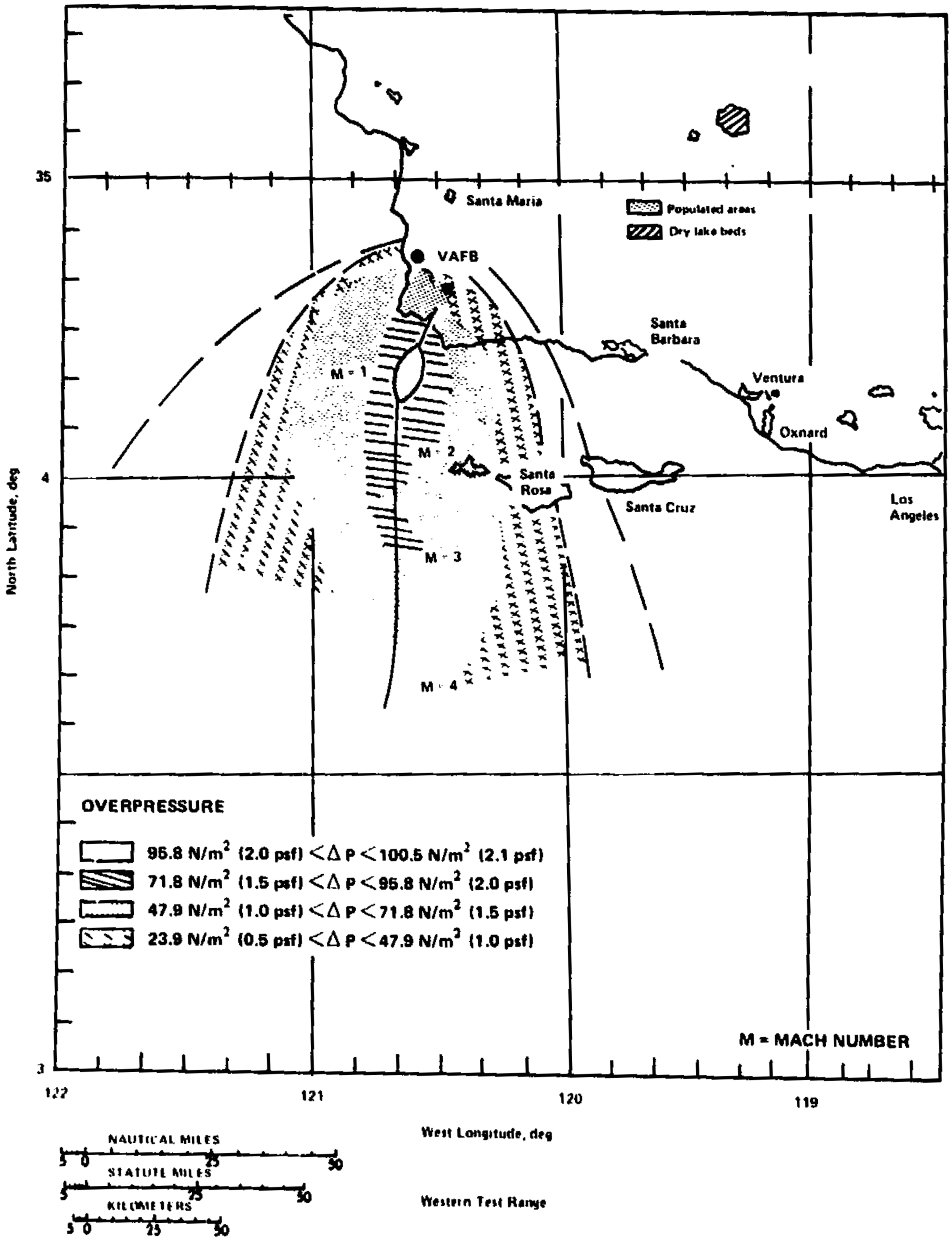

Figure 4-14.-- Sonic boom footprint for Vandenberg Air Force Base.

A high degree of behavioral habituation, even to intense impulse noises such as gunfire, is normally seen in animals and human beings when the exposure is repeated, provided that the character of the stimulus is not changed. Transient overpressures of considerable magnitude can be experienced under certain circumstances without significant discomfort. For example, the overpressures inside a car when the door is slammed (windows raised) are up to 200 N/m^2 (4 psf) for standard sedans and station wagons and up to 425 N/m^2 (8.5 psf) for compact cars. Overpressures of 600 N/m^2 (12 psf) have been measured in public viewing areas during firework displays.

The NAS/NRC Committee on Hearing, Bioacoustics, and Biomechanics (CHBB) has developed criteria for impulse noise, including an upper tolerance limit for impulse noise. Impulse noise levels which exceed the CHBB limit can produce cochlear damage and hearing loss. The CHBB limit for one impulse per day lasting about 200 msec (corresponding to a sonic boom) is a sound pressure level of about 145 dB (365 N/m^2); see reference 4-45.

The acceptability to the public of sonic booms below the CHBB impulse noise limit is very complex and involves not only the physical stimulus, but also various characteristics of the environment and the experiences, attitudes, and opinions of the population exposed (ref. 4-45). Information bearing on this question was developed in a comprehensive study of sonic boom exposure of a large community conducted in Oklahoma City in 1964. Interpretation of the data relative to the Space Shuttle is difficult because the community was exposed to as many as 15 booms per day. The effect of a single boom estimated from the multiple boom data was that the peak overpressure of a single sonic boom should not exceed 36 N/m^2 (0.7 psf) if the population is not to be annoyed (see ref. 4-45).

A summation of the Oklahoma City tests (ref. 4-47) was made by the International Civil Aviation Organization (ICAO). In reviewing the effects of sonic boom produced by supersonic aircraft during normal flight operations, the ICAO found that --

1. The probability of immediate direct injury to persons exposed to sonic boom is essentially zero.

2. The percentage of persons queried who rated sonic booms occurring 10 to 15 times daily as annoying increased with increasing overpressures. For overpressures of less than about 24 N/m^2 (0.5 psf), no one rated the boom as annoying; about 10 percent considered 48-N/m^2 (1-psf) sonic booms annoying; and nearly all considered 144-N/m^2 (3-psf) booms annoying.

3. Primary (loadbearing) structures meeting acceptable construction standards or being in good repair showed no sign of damage up to overpressures of about 950 N/m^2 (20 psf). Nonprimary structures such as plaster, windows, and bric-a-brac sustained some damage at overpressures ranging from 48 to 144 N/m^2 (1 to 3 psf).

Recent studies of the physiological effects of single sonic booms (ref. 4-48) gave results in general agreement with the ICAO findings. These studies showed that the effects of single sonic booms on human beings could be grouped into four broad classes, in each of which the

physiological effects of the boom were generally similar. These results are summarized in the following table (from ref. 4-48).

Sonic boom overpressures, N/m^2	Behavioral effects
16	Orienting, but no startle response
	Eyeblink response in 10% of subjects
	No arm/hand movement
30 to 111	Mixed pattern of orienting and startle responses
	Eyeblink in about half of subjects
	Arm/hand movements in about a fourth of subjects; no gross bodily movements
130 to 310	Predominant pattern of startle responses
	Eyeblink response in 90% of subjects
	Arm/hand movements in more than half of subjects; gross body flexion in about a fourth of subjects
340 to 640	Arm/hand movements in more than 90% of subjects

The effects of sonic boom on wildlife have not been studied, although some animal experiments have been done. For example, the reaction of captive minks to sonic booms has been observed (ref. 4-49). In this study, using 300-N/m^2 (6-psf) overpressure sonic booms, it was found that the minks were affected to the point of sticking their heads out of the cages. There were no frantic reactions or panic, and the minks shortly resumed their normal activities. Specific examples may exist, however, for which the startle associated with sonic booms and other impulsive noises may have a deleterious effect. It is significant to note that the ICAO reported (ref. 4-47):

> Experience from Concorde test flights over water and many years of military flying over the sea, in particular near land where many ships and small boats are found, has not yielded any evidence of human disturbance by sonic booms at sea.

When the horizontal velocity of the Shuttle is less than the speed of sound in water, equivalent to Mach 4.4 in air, the sonic boom from the Shuttle will propagate into the water as an acoustic wave, whose peak pressure attenuates rapidly with water depth (ref. 4-50). The pressure wave is

reduced to about one-tenth of its surface amplitude at a depth of 6 to 9 m (20 to 30 ft); see reference 4-51.

When the horizontal velocity of the Shuttle exceeds Mach 4.4, the sonic boom will propagate into the water as a shock wave. The peak pressure associated with the shock wave is not affected by water depth but attenuates as it does in the air.

The principal effect of the sound and shock waves on marine life is expected to be a startle reaction. Fish have been subjected to intense sonic booms of 27 500 N/m^2 (550 psf) without noticeable effects (ref. 4-52). The wave in these tests only lasted about 0.05 msec, much less than the 200-msec duration expected from the Space Shuttle. It is not known whether the difference in duration is significant.

4.5.5.2 Evaluation of Space Shuttle Sonic Boom Effects

During reentry, the sonic boom from the Space Shuttle will reach a maximum value of 101 N/m^2 (2.1 psf). This corresponds to an impulse sound pressure level of 134 dB, which is well below the CHBB damage limit of 145 dB. The focused portion of the launch boom could reach an impulse noise level of 157 dB, which exceeds the CHBB limit, but only over a narrow (200-m wide) region over water. Outside the narrow focus zone, the maximum impulse noise level of the launch sonic boom will be about 143 dB (less than the CHBB limit).

Animals, including special-interest marine animal species (pinnipeds) and endangered brown pelicans on the Channel Islands, may be exposed to sonic booms and sound focusing overpressures generated during Shuttle ascent from VAFB. The available data on the effects of sonic booms on wildlife and marine life indicate that the rentry and launch booms may produce startle effects.

The reentry sonic boom at 101 N/m^2 (2.1 psf) is at an intensity which falls into the second exposure level category, as shown in the table of section 4.5.5.1. At this level, startle reactions will occur in some people, but no gross bodily movements will occur.

An area about 60 x 120 km (27 x 74.5 miles), or about 7000 sq km (2760 sq miles), is contacted by the reentry boom (as seen from figs. 4-12 to 4-14). In Florida (fig. 4-13), this area contains about 500 000 people, since it includes the city of Orlando (although the boom intensity at Orlando is down to a 50- to 75-N/m^2 range). In California, the landing boom at DFRC contacts about 50 000 people, since most of the boom impacts sparsely populated regions northwest of Los Angeles (fig. 4-12). The landing at VAFB affects only a few thousand people, since most of the reentry boom impacts the Pacific Ocean (fig. 4-14).

4.6 Unplanned Events

A variety of unplanned events with possible undesirable environmental consequences can occur during the construction, manufacture, test, and operation of the Space Shuttle and its supporting facilities. In general,

events that would have a reasonably high probability of occurrence (even though unintentional) have been considered in the plann'ng of the program, and steps have been taken to reduce the probability to a low level and/or to mitigate the consequences. Thus, the events considered here are regarded as having a low probability either of occurrence or of significant deleterious environmental effects.

4.6.1 Support and Manufacturing Facilities

The Space Shuttle Program involves the preparation and operation of several manufacturing and support facilities (see section 2.3). Unplanned events which may occur during these activities include industrial-type accidents (e.g., those not involving particularly hazardous materials) and unplanned events associated with the hazardous materials peculiar to the Space Shuttle Program.

4.6.1.1 Industrial Accidents

Preparation and operation of the Space Shuttle's support and manufacturing facilities may result in personnel injuries, just as in any industrial operation. With the exceptions to be discussed below, the probabilities and consequences of such accidents in the Space Shuttle Program are not different from similar nonspace-related commercial operations. All construction and manufacturing activities associated with the Space Shuttle Program are conducted within the rules and regulations imposed by the Occupational Safety and Health Administration (U.S. Department of Labor) and the states where the activities occur.

4.6.1.2 Propellant and Fluid Spills

Potentially hazardous fluids handled in connection with the Space Shuttle Program are liquid hydrogen, MMH, hydrazine, and nitrogen tetroxide. Other fluids, such as liquid oxygen, liquid nitrogen, hydraulic fluids, or conventional hydrocarbon fuels (such as those used in the Boeing-747 Space Shuttle carrier aircraft) either present a much lower hazard or are handled in quantitites too small to be of major consequence.

Liquid hydrogen is extremely flammable, MMH, and hydrazine are flammable and toxic, and nitrogen tetroxide is toxic and under certain conditions can cause spontaneous ignition of combustibles.

4.6.1.2.1 Liquid Oxygen and Liquid Nitrogen Spills

Liquid oxygen is used as one of the main engine propellants, and liquid nitrogen is used as refrigerant and as a source of gaseous nitrogen. The Space Shuttle launchsite storage capacity at KSC is 3400 m^3 (900 000 gal) of liquid oxygen and 1900 m^3 (500 000 gal) of liquid nitrogen.

If spilled in large quantities, either liquid oxygen or liquid nitrogen could cause local damage because of the intense cold, 90 and 77 K (-247° and -320° F), respectively. Liquid oxygen, if mixed with finely divided combustible material, forms explosive mixtures. The gaseous oxygen evaporating from the liquid oxygen will also intensify any pre-existing fire. The gaseous nitrogen evaporating from a liquid nitrogen spill is inert, but in high concentrations it is an asphyxiant. Industrial standards prohibit asphyxiant concentrations that reduce the oxygen concentration below 18 percent. This would correspond to the 17-percent addition of nitrogen to air.

Both liquid oxygen and liquid nitrogen are commercial materials handled in vast quantities (see table 8-3), but spills are not frequent. There have been no reports of lasting environmental damage caused by such spills or of damage beyond the small localized areas involved in the spills. There is no indication that even the largest possible spill at the launchsite would endanger the public or the ecology of any area except that involved in the immediate spill.

4.6.1.2.2 Monomethylhydrazine, Hydrazine, and Nitrogen Tetroxide Spills

Handling of MMH, hydrazine, and nitrogen tetroxide is recognized as a hazardous operation because of their toxicity and spontaneous flammability when nitrogen tetroxide and the hydrazine are mixed. For a workroom environment, the threshold limit values for MMH, hydrazine, and nitrogen tetroxide as nitrogen dioxide (table 4-9) are 0.2, 0.1, and 5 ppm, respectively (the current threshold limit value for hydrazine is 1 ppm, but a change to 0.1 ppm is intended). Limits for MMH and nitrogen tetroxide are for inhalation, whereas those for hydrazine are for overall exposure by the cutaneous route. Extreme precautions are taken, and quarterly personnel qualification/certification training on the handling of spills (among other things) is given. The actual fluids are used in these training classes.

The maximum stored quantities of nitrogen tetroxide and MMH at the Space Shuttle launch pad are about 32 m^3 (8600 gal) each, which is substantially less (almost one-half) than the quantity used in a single Titan-III launch. Only small quantities of hydrazine are used, only 675 kg per launch.

The potential consequences of spills of MMH or hydrazine and nitrogen tetroxide have been described in other environmental statements (e.g., refs. 1-1, 1-5, 1-9, and 4-38). Spills at the launchsite have been shown to offer no significant hazard beyond the site boundaries. Within the site boundaries, provisions are made to contain the spilled liquids and dispose of them in an environmentally acceptable manner: by incineration, neutralization, or controlled dilution and release.

4.6.1.2.3 Liquid Hydrogen Spills

The liquid hydrogen storage tank at the KSC Space Shuttle launch pad has a capacity of 3200 m^3 (850 000 gal). A total of 1405 m^3 (383 000 gal) is loaded into the External Tank for each Space Shuttle launch.

Spills of liquid hydrogen present an extreme fire hazard and under certain circumstances may also present an explosion hazard. In these respects, liquid hydrogen differs in degree but not in kind from the hazards associated with common commercial products such as propane. It may be noted that on a volumetric basis, the heat released by liquid hydrogen is smaller than that released, for example, by propane or gasoline. Liquid hydrogen spills will either ignite immediately or at some later time. Ignition immediately following the spill will cause a flash as the inventory of gaseous hydrogen is burned, followed by burning above the pool of evaporating liquid. As in any large fire of a volatile liquid, destruction in the involved area will be extreme. In terms of environmental effects, the major feature of such a large fire will be the thermal radiation. With normal atmospheric humidity, the thermal radiation from the flash (which may last for 30 sec) is estimated to be about 2 cal/cm^2 at a distance of about 300 m (950 ft) for a 3200-m^3 (850 000-gal) spill. The approximate threshold limit value to cause first-degree burns to exposed skin is 2 cal/cm^2; it is also the approximate threshold value for igniting paper and other light combustibles. The radiation from the burning pool is estimated to be less by a factor of about 5 than the flash radiation.

If the spilled liquid hydrogen evaporates without burning, the cloud of gaseous hydrogen may be carried downwind and ignited at some downwind position. The greatest distance at which ignition can occur will depend on meteorological conditions which govern the dispersion of the cloud. The high molecular diffusivity of hydogen will augment the meteorological dispersion. Once the highest concentration of hydrogen in the cloud reaches the lower flammable limit (the lowest concentration which is flammable), ignition and burning can no longer occur. Any process that is sufficiently violent to cause accidental rapid release of large quantities of liquid hydrogen would be expected to cause some spark, hot spot, or damage to near-by power devices which would ignite the hydrogen immediately. Gaseous hydrogen has the lowest ignition energy requirement of any fuel which does not ignite spontaneously.

Mixtures of hydrogen and air near the chemically correct proportions can explode or detonate. However, for unconfined hydrogen and air mixtures, ordinary ignition sources do not cause detonation. Because immediate ignition is expected for a large, rapid spill and because detonation may not be caused by ignition by ordinary sources, detonation of the hydrogen cloud is not considered a likely event.

In summary, if a large hydrogen spill should ignite, extensive damage to a localized area would result, including death or serious injury to persons within that area. However, environmental damage outside that area would be small or negligible. The rapid spilling of large quantities of liquid hydrogen without immediate ignition is improbable because an extremely violent event would be required to initiate the process. Although spontaneous catastrophic failures of large tanks have occurred (e.g., the molasses tank in Boston and the liquefied natural gas tank in Cleveland), the causes of these failures are now understood and avoided through improvements in design and inspection techniques and in metallurgy.

4.6.1.3 Accidental Ignition of SRM Propellant, Segment, or Motor

It is unlikely that a Space Shuttle SRM casting segment would be accidentally ignited during SRM processing, handling, or transportation operations. However, emissions from the occurrence of such an event have been predicted (ref. 1-6). The total emissions are as follows.

Species	Amount, kg		
	Forward	Center	Aft
Aluminum oxide	38 700	35 300	34 600
Carbon monoxide	33 400	30 500	29 900
Hydrogen chloride	23 100	21 000	20 700
Water	12 200	11 100	10 900
Nitrogen	11 800	10 800	10 600
Chlorine	4 900	4 500	4 400
Carbon dioxide	3 800	3 500	3 400
Hydrogen	2 600	2 400	2 300

Afterburning effects would significantly reduce the carbon monoxide concentration and modify the partitioning of hydrogen chloride and chlorine to some extent. Nitrogen oxides could be formed, but the total amount would be small compared to other species.

The following table presents the predicted peak ground-level concentrations and dosages of hydrogen chloride, chlorine, and aluminum oxide for the most unfavorable meteorological condition investigated resulting from ignition and burning of an SRM segment (ref. 1-6).

Peak concentration:

Hydrogen chloride, ppm	14
Chlorine, ppm	1.6
Aluminum oxide, mg/m^3	31

Maximum integrated dose:

Hydrogen chloride, ppm-sec	2040
Chlorine, ppm-sec	228
Aluminum oxide, mg/m^3-min	75

When compared with the criteria listed in table 4-5, the predicted value for hydrogen chloride does not exceed the criterion for emergency or accidental exposures. Also, the maximum 24-hr average aluminum oxide concentration expected is 0.052 mg/m^3 and does not exceed the 24-hr average particulate concentration criterion of 0.26 mg/m^3 (primary standard) or 0.15 mg/m^3 (secondary standard). The model used to predict these values is discussed in appendix C. There, the predicted values are conservative, with the actual values significantly lower.

Complete motors will exist only after assembly at a test site or launchsite, where complete control of the environment and access are possible. The consequences of an accidental ignition on the launch or test pad would be similar to those of the normal test described in section 4.2. Ignition of an unsecured motor would cause the SRM to become an uncontrolled missile with possibly catastrophic effects along the unpredictable path taken by the motor. Every precaution is taken to ensure against this event.

4.6.2 Mishap During Transportation of Hardware, Propellants, and Fluids

The individual components of the Space Shuttle (Orbiter, External Tank, SRB's) and various ancillary components and supplies must be transported between various supply and manufacturing sites, test sites, and launchsites. The possible consequences of mishaps during transportation are discussed in the following paragraphs.

4.6.2.1 Space Shuttle Orbiter

The Orbiters will be transported between EAFB and the launchsites and elsewhere as required by ferrying piggyback on a specially adapted Boeing-747 aircraft (the Space Shuttle carrier aircraft). The Orbiter will be transported overland between the manufacturing and overhaul site in Palmdale and EAFB.

The behavior of the aircraft with the Orbiter attached has been carefully studied in wind tunnel tests and is being fully evaluated in flight tests at a remote site (EAFB/DFRC). As a result, the ferrying operation will be no more hazardous than any commercial flight of a large aircraft.

Although no fuels will be aboard the Orbiter, a small amount of pyrotechnic materials for crew safety systems will be installed at Palmdale prior to transport. All pyrotechnic devices will be deactivated during transport operations. It is unlikely that these devices could be activated during transport; and even if they were, the effects would be minimal.

The Orbiter will be towed over the local roads on a commercial transporter between the manufacturing site in Palmdale to the EAFB/DFRC for testing or transfer to the Space Shuttle's carrier aircraft. No mishaps leading to significant environmental damage have been identified.

4.6.2.2 SRM and SRB Separation Motors

The consequence of a mishap during transportation of an SRM segment has been examined (ref. 1-6). It does not differ from the analysis given in subsection 2.3.2.4. The same analysis can be applied to the solid propellant separation motors, with appropriate allowance for the much smaller quantities of propellant. It was concluded that the probability of a mishap igniting the segment (the only effect of significance) was small. It was also shown that the area affected would be small and probably not of significant consequence unless the mishap occurred in an urban area. The SRM segments and the SRB separation motors represent far less hazardous cargo than other industrial materials carried in far larger amounts (e.g., high explosives, vinyl chloride, carbonyl chloride).

4.6.2.2.1 Recovery of the Solid Rocket Booster

The SRB motors will be parachuted into the ocean approximately 240 km (150 miles) from the launchsite. Retrieval vessels will recover the parachutes and tow the empty SRB to land for refurbishment and reuse. Transportation mishaps associated with this recovery operation are impact of the SRB on the recovery vessel or other vessel, loss through sinking of the SRB, and mishaps associated solely with the operation of the recovery ship and not specifically with its use for SRB recovery.

SRB impact will occur in a predicted elliptical zone about 18 x 60 km (11 x 38 miles). Warnings are provided to aircraft and ships before the launch, and the predicted impact area is maintained under surveillance. The recovery vessel is posted at a safe distance from the impact area; SRB impact on a vessel is thus highly improbable. The empty SRB is effectively inert. It will contain a small amount of residual hydrazine in tanks designed to withstand the splashdown loads and the salt water environment without leakage. Early SRB's will carry a linear shaped charge as part of the flight termination system for range safety; however, this ordnance will be both mechanically and electrically "safed" (made inert) prior to SRB separation. If the SRB should sink in deep water, no hazard would be presented to shipping or to the marine environment. If the SRB should sink in shallow water, it would be recovered because of its value. Hence, no hazard would result to either ships or to the environment. Mishaps to the retrieval vessel will not result in any environmental consequences different from those associated with any shipping mishap (excluding oil tankers). The retrieval vessel is powered by ordinary petroleum-based fuels. Normal safety precautions will be observed in handling these fuels.

4.6.2.3 External Tank

The External Tank will be assembled at the MAF and transported to the various test sites and launchsites by barge or ocean vessel. During transport, the External Tank contains no hazardous fluids or materials. Similar large, inert items (usually much heavier) such as reaction vessels and distillation columns are routinely shipped in commercial operations. Mishaps enroute will cause no environmental effects different from identical mishaps

not involving the External Tank. There is no reason to expect that the presence of the External Tank will increase the probability of such mishaps.

4.6.2.4 Liquid Propellants and Fluids

Shipment of the various potentially hazardous propellants and fluids is by the following modes.

Fluid	Mode
Liquid nitrogen	Tank truck
Liquid oxygen	Tank truck
Liquid hydrogen	Tank truck (current)
Liquid hydrogen	Barge or rail tank car (under consideration)
MMH	Rail tank car and truck
Nitrogen tetroxide	Rail tank car and truck

With the exception of MMH, all of these materials are shipped commercially as bulk commodities in large volumes. The hazard resulting from a mishap during transport is no greater (and frequently much less) than that resulting from a mishap involving other toxic and flammable gases and liquids transported in commercial operations.

MMH is not an item of normal commerce; however, its toxicity, as represented by the threshold limit value, is comparable to that of many commercial chemicals manufactured and shipped in large quantities. For example, toluene diisocyanate, an ingredient of urethane plastics, is assigned a threshold limit value of only 0.02 ppm; and many pesticides have threshold limit values comparable to MMH.

In all cases, the significant consequence of a transportation mishap would be the release of the propellant or fluid to the environment. The effects of such release would be the same as discussed previously for spills at the launchsite, except that the location of the spill would not be on controlled property and provisions for containing spills (such as dikes) would be absent. In most cases, however, the maximum quantity of propellant or fluid that could be involved in a transportation mishap would be substantially less than in a postulated onsite spill.

Transportation mishaps causing the release of MMH or nitrogen tetroxide would create a toxic hazard in the locality of the mishap through evaporation into the atmosphere. Contamination of surface water, most serious for MMH, would occur if the spilled fluids entered local drainage systems. Soil contaminated with MMH may need to be removed and incinerated or deeply buried.

Because both MMH and liquid hydrogen are flammable, transportation mishaps involving these materials may result in fires; in fact, serious mishaps involving liquid hydrogen would be almost certain to result in a fire. The consequence of such fires would depend on the exact location of the mishap and could vary from being trivial to being locally serious.

The effects of a release of large quantities of liquid nitrogen or liquid oxygen in a transportation mishap would be highly localized. Either fluid could cause localized damage to ecosystems because of the extreme cold. Evaporation of large liquid nitrogen releases could also cause asphyxiation of animal life in the immediate vicinity of the release. Neither liquid oxygen nor liquid nitrogen would cause any long-term degradation of air, water, or soil quality.

Transportation of propellants and fluids is regulated by the U.S. Department of Transportation, and all regulations and rules are observed. When water transport is involved, the rules and regulations of the U.S. Coast Guard are observed. Current regulations require that rail trains transporting hazardous materials carry information on the specific materials and their location in the train. Services supported by the chemical industry (e.g., Chem Trek) also provide information to local emergency personnel for dealing with hazardous materials involved in transportation mishaps. These regulations and services assure that should a mishap occur, the needed information for emergency action and decontamination is available to local personnel.

4.6.2.5 Solid Propellant Ingredients

The major solid propellant ingredients are ammonium perchlorate, PBAN, and aluminum powder. Other materials used in small quantities include an epoxy curing agent and iron oxide. These are standard ingredients for solid rocket propellants and have been produced and transported in large quantities in connection with past (military) programs. Transportation is by truck or by rail and truck.

None of these materials is regarded as unusually hazardous in transport. Ammonium perchlorate and PBAN are toxic by ingestion. Acrylonitrile, an ingredient of PBAN, has an assigned threshold limit value of 20 ppm, but the low vapor pressure of PBAN makes inhalation a hazard only in confined spaces. All of the materials present some degree of fire hazard. There is a remote possibility of a detonation occurring in ammonium perchlorate, just as in ammonium nitrate, a commonly used fertilizer. Should ammonium perchlorate be involved in a fire as a result of a transportation mishap, hydrogen chloride and probably nitrogen oxides would be released to the atmosphere. The consequences would be similar to those of an accidental ignition of an SRM segment.

Under typical circumstances, spills of these materials in a transportation mishap can be easily controlled and decontaminated. Transportation fires involving ammonium perchlorate would release toxic gases and would be difficult to extinguish, but these characteristics are shared by many shipments of commercial chemicals. No serious environmental effects are envisioned as a result of transportation mishaps.

4.6.3 Orbiter Approach and Landing Tests

The Orbiter ALT's were conducted at EAFB/DFRC. Significant tests involved carrying the Orbiter to altitude with the Space Shuttle's carrier aircraft, separating the Orbiter from the aircraft, and descending and landing the Orbiter. In preparation for these flights, the ALT program included taxi tests and flight tests of the mated Orbiter carrier aircraft.

These tests were similar to those conducted on any new aircraft or aircraft configuration and thus included an element of risk. However, such tests were undertaken only when analysis and ground-based tests indicate that the test may be conducted safely and successfully. The tests were also performed sequentially so that if unexpected problems do occur, they can be identified and corrected before a catastrophic situation develops.

The most serious mishap that might have occurred during the ALT was a crash of the carrier aircraft and/or the Orbiter. In the remote unpopulated areas where the ALT's were conducted, the environmental consequences of a crash would have been minimal.

4.6.4 Crew Training

The Orbiter's flight crews will be trained in two modified Gulfstream-II aircraft, the Space Shuttle training aircraft. The aircraft will be based at Ellington Air Force Base, Texas; and training flights will be made at EAFB, KSC, VAFB, and White Sands Test Facility.

The training aircraft in the Orbiter's simulator configuration is a highly unconventional aircraft, and the possibility of accidents in this configuration could be considered somewhat greater than for conventional aircraft. However, the aircraft is designed for quick reconfiguration from a simulator to a conventional operation in the event of an emergency; it is always monitored by a safety pilot during simulations; and all simulations will be made in controlled air space at government facilities.

4.6.5 Parachute Tests

The SRB recovery parachutes will be tested by dropping a 23 000-kg (50 000-lb) mass attached to the parachute system from a B-52 aircraft. The tests will be conducted at the National Parachute Test Range near El Centro, California. The aircraft will be based at EAFB. Mishaps which can be conceived are inadvertent release of the mass and parachute system and crash of the aircraft. Both types of mishaps represent hazards to life and property, and normal safety precautions will be taken to avoid such hazards.

4.6.6 Engine Tests

Rocket engines used on the Space Shuttle, together with their thrust levels and test sites, are as follows.

Engine	Thrust, kN	Test site
Main engine	1668/5004	NSTL, KSC, Santa Susana Facility
SRB	11 800	Thiokol
Separation motor	100	UTC/CSD
OMS	26.7	White Sands
RCS	3.9/0.1	White Sands

Unplanned events that might occur during engine testing and which require consideration here are fires, explosions, and the inadvertent release of toxic materials.

4.6.6.1 Main Engine Tests

The main engine tests consist of engine development tests at the Rocketdyne facility at Santa Susana, California; tests of single engines and clustered engines at the NSTL, Mississippi; and flight readiness tests at KSC Space Launch Complex 39. The main engine's propellants are liquid hydrogen and liquid oxygen; hence, no toxic materials are involved in the tests. All test sites are sufficiently remote that no hazard is presented to the public by fires or explosions. Explosions occurring during the testing of liquid propellant or engines would be of low equivalent yield and would not be expected to cause significant damage beyond the immediate test stand. Typically, fires would be intense but brief and would not cause damage beyond the immediate test stand. No extensive or lasting environmental effect is expected for any creditable mishap.

4.6.6.2 Solid Rocket Motor Tests

The SRM will be test-fired at the Thiokol/Wasatch plant. Test firings (seven in all) are restricted to the SRM development and qualification: No test firings are planned after the qualification tests. Unplanned events during the SRM test firings that need be considered are rapid deflagration, fires, and the abnormal release of toxic exhaust gases. These events have been examined in the environmental statement for the SRM (see ref. 1-6). It was shown that neither the deflagration of the motor nor the release of toxic combustion products from a malfunctioning motor would create a hazard other than in the immediate vicinity of the test site from which personnel are excluded during tests. Grass or brush fires could be ignited by a malfunctioning SRM. To prevent the spread of such fires, an extensive

system of firebreaks is maintained at the Thiokol site; and firefighting personnel and equipment are available.

4.6.6.3 Separation Motor Tests

The SRB separation motor will be tested at the UTC/CSD remote site at Coyote, California. The test site has been used in previous programs for testing solid propellant rocket motors containing up to 268 000 kg (592 000 lb) of propellant. The separation motor will contain only 30 kg (65 lb) of propellant. Generally, the same unplanned events considered for the SRB apply for the separation motor. The much smaller size of the separation motor assures that none of the events will lead to a public hazard or to significant environmental damage.

4.6.6.4 Tests of the Orbital Maneuvering and Reaction Control Systems

The OMS and RCS engines and systems will be tested at the White Sands Test Facility, located in a sparsely populated remote area. An environmental impact statement (institutional statement) has been prepared for the White Sands Test Facility (ref. 1-7). Since 1964, the facility has been used for testing rocket engines using propellants such as MMH and nitrogen tetroxide.

Possible explosions or fires during testing of the OMS and RCS engines may damage the test stands, but no other consequences are expected. The inadvertent release of toxic vapors of MMH or nitrogen tetroxide will not result in toxic concentrations beyond the controlled area. Facilities are maintained for cleanup and neutralization of toxic liquids that may be spilled during a mishap. Thus, no environmental effects of significance are anticipated to result from mishaps during OMS or RCS test firings.

4.6.7 Space Shuttle Ground Operations

During assembly and processing just before the launches at KSC, it is planned to mate the SRB segments on the mobile launch platform. Eight SRM segments will therefore be in a temporary holding status in the vertical assembly building for each launch. Accidental ignition of a complete SRM is considered far less likely to occur than accidental ignition of the propellant or a segment. Fire and toxic combustion products are the hazards involved. The quantities of toxic products involved will be the sum of the individual segments. However, afterburning will modify the exhaust species as mentioned previously. Ignition at the assembly areas will not cause environmental damage much beyond the areas affected which are well within the controlled boundaries of the two launchsites. The toxic combustion product concentrations are quickly reduced below the threshold of toxicity for plants and animals by mixing with the ambient atmosphere.

4.6.7.1 Space Shuttle Launch Operations

Unplanned events which might occur during Space Shuttle launch operations include explosions, fire, the release of toxic gases, crash, or mission abort.

4.6.7.1.1 On-Pad Fire or Explosion

The most serious consequence of an on-pad fire involving the entire Space Shuttle vehicle will be the release of toxic combustion products from the SRB's. The large heat release associated with the burning of the main engine's propellants will assist the cloud of combustion products in rising to a high altitude. Although the quantity of SRB combustion products released at ground level will exceed that released at or near ground level in a normal launch, the additional heat and cloud rise contributed by the main engine's propellants will compensate in terms of ground-level concentrations of hydrogen chloride and chlorine. Analyses of on-pad solid propellant fires have shown that even in the absence of an associated liquid propellant fire, the public emergency exposure limits are not exceeded at ground level. The "worst case" result of an analysis for an SRB fire at the KSC launchsite, using weather data for 1969, was performed by MSFC and is given in table 4-10.

Explosions on the launch pad might achieve significant blast effects under special circumstances. Such circumstances would be those that lead to sudden rupture of the External Tank: Fallback of the Space Shuttle or some gross structural failure of the External Tank or its supports might represent such events. The explosive yield which would result from the hydrogen and oxygen propellants is predicted to be 20 percent. In a worst-case situation, if the explosive yield is taken as 100 percent and an explosion equivalency of 28 kg (61.6 lb) of dynamite per kilogram of hydrogen is used, then the explosion would be equivalent to the detonation of 2.9×10^6 kg (6.3×10^6 lb) of dynamite. The distances to which various adverse effects could be expected are as follows (ref. 4-53).

Effect	Threshold blast wave pressure, N/cm^2 (psi)	Distance from launch pad, m (ft)
Glass breakage	0.34 (0.5)	4000 (13 000)
Penetrating missiles	1.4 (2)	1500 (4900)
Eardrum rupture	3.4 (5)	800 (2600)
Lung injury	6.9 (10)	500 (1600)
Lethal	21 (30)	300 (1000)

Immediately prior to launch, all unprotected personnel are evacuated from the launch pad. Consequently, no injuries other than to the flightcrew are anticipated, even for this worst-case event.

TABLE 4-10.- SURFACE MAXIMUM CENTER-LINE HYDROGEN CHLORIDE CALCULATIONS FOR A SPACE SHUTTLE SLOW BURN

(Model 3, 7 p.m., March 5, 1969)

Range, m	Azimuth bearing, deg	Maximum peak concentration, ppm	Maximum dosage, ppm-sec	Approximate 10-min time - mean concentration, ppm	Time of cloud passage, sec	Average cloud concentration, ppm
2 000	145.7	0.000	0.000	0.000	210.035	0.000
3 000	144.7	.010	1.296	.002	214.781	.006
4 000	144.8	.249	32.402	.054	223.426	.145
5 000	145.4	.794	109.062	.182	235.616	.463
6 000	146.0	1.281	187.006	.312	250.873	.747
7 000	146.7	1.544	242.289	.404	268.679	.900
8 000	147.2	[a]1.607	270.350	.451	288.540	.937
9 000	147.6	1.541	[a]278.383	[a].464	310.066	.898
10 000	148.0	1.411	273.128	.455	332.942	.822
11 000	148.4	1.258	264.134	.440	356.923	.733
12 000	148.8	1.107	246.810	.411	381.799	.646
13 000	149.1	.970	230.440	.383	407.409	.565
14 000	149.4	.850	214.744	.357	433.618	.495
15 000	149.7	.747	199.853	.331	460.329	.435
16 000	150.1	.660	187.538	.310	487.465	.385
17 000	150.3	.586	175.831	.289	514.938	.341
18 000	150.6	.523	165.404	.271	542.698	.305
20 000	151.0	.424	148.082	.239	598.931	.247
22 000	151.4	.350	133.806	.212	655.886	.204
24 000	151.7	.294	121.980	.189	713.385	.171
26 000	152.0	.250	112.376	.170	771.323	.146

[a]Maximum.

4.6.7.1.2 Ascent Accident

Public safety from hazards associated with the launch and ascent of the STS vehicle is the responsibility of the range commander. For early flights, this is exercised through the capability for ground-commanded flight termination (vehicle destruct) to prevent impact on land should the vehicle depart radically from its nominal flightpath. This protection of the public is provided until the vehicle achieves orbit and will be assured for every flight until such time as the range commander has established that the demonstrated reliability of the vehicle permits removal of the ground-controlled flight termination system.

4.6.7.1.3 Early Mission Abort

Contingency plans for operational emergencies during launch are based on the position of the launch trajectory where the emergency occurs. For emergencies occurring early in the flight, the SRB's will be jettisoned at burnout (up to 127 sec minimum burn), and the main engine and OMS propulsion systems will be used as needed to make an in-plane turn. The External Tank will be jettisoned, and the Orbiter will glide back to a landing at the launchsite. Emergencies occurring later in flight will result in either the Orbiter's return to one of the launchsites, to the alternate landing site at EAFB, or to a contingency landing site such as Guam or Hawaii after one suborbital revolution of the Earth or continuation in orbit. In all these cases, the trajectory and SRB drop zones will be essentially the same as in a normal flight. The External Tank may be dropped other than in the planned drop zone. This is discussed in the following section.

4.6.7.2 External Tank Jettison

In a normal mission, the External Tank will be jettisoned to impact in a preplanned ocean area remote from shipping zones. Additionally, the impact area will be announced to air transporters and shippers before the flight. This practice is identical to that used in current spaceflight activity to protect aircraft and ships from reentry of suborbital rocket stages. In case of an early mission abort, the External Tank may be jettisoned into the ocean near the launchsite. A portion of the possible impact area coincides with the launch corridor where warnings are issued to aircraft and ships before the launch and which is under surveillance during launch operations. Because the External Tank will not contain toxic materials, the hazard to the environment from impact either in the preplanned area or elsewhere will be confined to physical effects at the impact point.

4.6.7.3 Jettison of the Solid Rocket Booster

Damage to the environment would be limited to the physical effects of the impact, as the SRB's are inert after burnout. In a normal flight or in an abort, the SRB's will descend to the preplanned ocean area recovery zone by parachute. The location of the recovery area is announced to aircraft and ships before launch, and the area is maintained under surveillance.

If the SRB parachute were to fail, the SRB would still impact within the preplanned zone. The SRB might be damaged beyond further usefulness or sink and be lost, but no environmental hazards would result.

4.6.7.4 Orbiter Landing

For the first four Space Shuttle flights (part of the flight test program), the Orbiter will land at EAFB. Subsequently, the Orbiter will land at KSC or VAFB, depending on the launchsite. When landing, the Orbiter contains a minimum quantity of propellants (MMH and nitrogen tetroxide).

Should the Orbiter crash, the consequences would be similar to those of any large aircraft crash, except the fire which frequently follows the crash of conventional aircraft. Because the Orbiter will contain only minimal quantities of propellants, any postcrash fire will be more confined, less intense, and shorter lasting than fires accompanying the crash of conventional aircraft.

In conventional aircraft operations. which should closely resemble Orbiter atmospheric flight operations, the most probable location of a crash on landing is near or on the runway. The initial Orbiter landings will be made at the remote EAFB. The Orbiter's landing fields at both KSC and VAFB are well within the facility boundaries. Contingency landing sites such as Guam and Hawaii are available.

4.6.8 Effect of Unplanned Events on the Marine Environment and Water Quality

The potential impact of unplanned Space Shuttle operational events on the marine environment and water quality are limited to the following: in-flight failures which may result in vehicle hardware and propellant landing in the ocean and on-pad accidents and propellant spills which may result in run-off of propellants to local drainage systems.

The potential sources of pollutants during unplanned events and the major pollutants are as follows.

Potential source	Major pollutant
Solid propellants	Ammonium perchlorate (NH_4ClO_4)
Liquid propellants	MMH Hydrazine (N_2H_4) Nitrogen tetroxide (N_2O_4)
Lubricants, hydraulic fluid	Hydrocarbons

4.6.8.1 In-Flight Failures

Possibilities of pollution are primarily associated with toxic materials which may be released to and are soluble in the marine environment. Rocket propellants are the dominant source of such materials. A secondary consideration relates to oils and other hydrocarbon materials which may be essentially immiscible with water but, if released, may float on the surface of the water. The quantities of hydrocarbons used are small (table 8-1). In case of an in-flight failure in the early stages of flight, the impact of the SRB and Orbiter's External Tank would probably be intact. The Orbiter would be expected to separate intact and return to the launchsite.

Table 4-11 shows the amounts of propellant remaining in the SRB and the Orbiter at various times during the ascent phase and thus potentially available for release to the environment at that point in normal flight or after an abort. The downrange location of the corresponding impact points is also shown.

TABLE 4-11.-- AMOUNTS OF PROPELLANT REMAINING IN THE SOLID ROCKET BOOSTER AND THE EXTERNAL TANK DURING ASCENT

Time from launch, sec	SRB		External tank	
	Propellant remaining, kg	Impact point,[b] km	Propellant remaining, kg	Impact point,[b] km
0	1 005 000	0	715 000	0
50	602 000	46.3	646 000	46.3
100	201 000	116.7	574 000	116.7
[a]127	355	257	531 000	257
150	59-77		501 000	318
330			231 000	1090
490			14 900	5000

[a]Staging.

[b]Downrange location from launchsite.

The SRB propellant would continue to burn with the products of combustion as listed in table 4-1 being dispersed into the air or absorbed into the ocean water. Any unburned solid propellant would slowly disperse.

Table 4-9 (ref. 4-38) shows the estimated MAC's for the chemical species of concern. The values in table 4-9 are estimates for trout and are not expected to differ significantly for many fish species. Threshold limit values in air for man are shown for comparison. The most critical material is MMH.

The impact of the Orbiter's External Tank would release liquid hydrogen and liquid oxygen, which would burn or evaporate rapidly into the atmosphere. The MMH is contained in the Orbiter only and would be returned to the launchsite. However, if the Orbiter were forced to abort to a water landing, this material would enter into the water. The quantities listed in table 8-1 would be the maximum involved and are expected to dilute to nontoxic levels of concentration within the area affected by the emergency landing.

In order to assess the impact of in-flight failures, it was assumed that the maximum possible amount of toxic material was released into the sea, and the volume of water required for dilution to the MAC was calculated. Results for MMH, nitrogen tetroxide, hydrazine, ammonium perchlorate, and hydrogen chloride were as follows.

Chemical compound	Affected volume of seawater, liters	Dimension of cube containing affected volume, meters
MMH	3.8×10^9	156
Nitrogen tetroxide	8.3×10^7	44
Hydrazine	9.6×10^8	99
Ammonium perchlorate	1.4×10^{10}	240
Hydrogen chloride	*5.9×10^{11}	*830

*Dilution to pH = 5, neglecting the buffering capacity of seawater.

A qualitative sense of the potential size of the region affected by an in-flight failure is given by the last column in the table, which expresses the linear dimension of a cube containing the affected volume. Small schools of fish could be affected, but no large-scale or permanent effects on marine life are expected. These compounds are all chemically active and are not expected to persist in the marine environment.

4.6.8.2 On-pad Accidents and Propellant Spills

Provisions such as dikes and catch basins are made for containing on-pad spills and disposing of the spilled propellant without contaminating the water environment. On-pad vehicle failures would normally be

expected to result in a fire that consumed most of all of the propellants (section 4.6.7.1.1). Any unconsumed propellant would be treated in the same way as a spill. The threshold limit values in air for human beings in a workroom environment are given in table 4-9. These would apply to spills in a confined area. The threshold limit values in unconfined spaces for MMH, hydrazine, and nitrogen oxides are given in table 4-5(b). The MAC's of various propellants in water are shown in table 4-9.

4.7 Culture

The following subsections describe the cultural effects caused by the Space Shuttle Program. The following discussions include employment and historic, archeological, and recreational factors (land-use factors are discussed in section 3). Where appropriate, information is presented on specific sites where most of the Space Shuttle activities are taking place. Otherwise, these various cultural factors assume a more general or "total program" scope.

4.7.1 Economics

The full development of the Space Shuttle, the initial investment required, and its subsequent operation, together with continuing programs in science, applications, and aeronautics, can be supported at an essentially constant total NASA budget level; i.e., at about $4 billion in FY 1978 dollars. The peak annual total funding level required for the Shuttle development period is estimated at being between $1.2 and $1.3 billion.

The development costs for the Space Shuttle alone, not the STS, are now estimated to be $7.02 billion (FY 1978 dollars). Additional investment costs for procurement of production flight hardware are estimated at about $2.42 billion on the assumption that the initial inventory include three production Orbiters and two refurbished development-phase Orbiters.

Space Shuttle facilities and facility modifications at KSC and VAFB are estimated at $1.25 billion. Spacelab development is estimated at $177 million to NASA and $546 million to the ESA. Upper stage development is estimated at $219 million for the USAF-developed interim upper stage and the commercially developed solid spinning upper stage. Thus, the total investment required to develop the Space Shuttle and procure and develop other STS elements and operational facilities is approximately $11.63 billion.

A recent combined mission model for NASA, DOD, and other users calls for about 560 flights over a 12-year period (1980 to 1991), an average of less than 50 flights per year. Models like this one are not approved plans but provide assumptions that test the reasonableness of developing the Space Shuttle from an economic standpoint. This 560-flight STS traffic model was developed jointly by NASA and the USAF in response to a request by the Office of Management and Budget for an updated mission model and Shuttle fleet size analysis.

In this model, launch and launch-related costs were estimated to be about $12.7 billion over those 12 years (all costs shown in FY 1978 dollars). During transition from expendable launch vehicles to the Space Shuttle, about $2.7 billion was required for a total 12-year transportation requirement of about $15.4 billion.

The total cost of the Space Shuttle Program (development, 12 years of operation, payload procurement, and transition from expendable launch vehicles) is estimated to be approximately $17.8 billion less than conducting a comparable program with expendable launch vehicles.

Most of the money to be spent on the development of the Space Shuttle has already been committed to various contractors located throughout the United States. Figure 4-15 shows the distribution of Space Shuttle funding commitments for both DDT&E and production activities on a state-by-state basis. The largest proportion of the economic commitment is in the states of California, New York, Texas, Florida, Minnesota, Louisiana, Maine, and Missouri.

4.7.2 Employment Factors

The Space Shuttle Program has not produced any large changes in NASA civil service manpower at the various NASA centers. Consequently, the demographic impact of the Space Shuttle Program is due principally to the employment peaks produced by NASA contracts with private industry.

The costs and manpower for the development phase of the Space Shuttle Program are well defined. The manpower requirements for this phase are shown in figure 4-16; it shows employment in direct support of the Space Shuttle as a function of calendar year. Employment in this phase reached a peak of about 45 000 in 1976 and is currently decreasing. The workers are geographically dispersed throughout the United States (see fig. 4-15), so that only in local regions with major contractors is there any possibility of a significant employment effect. These regions include Downey, California (where Orbiter subassemblies are fabricated); Palmdale, California (where the Orbiter assembly is completed); Santa Susana, California, and Bay St. Louis, Mississippi (where the main engine is tested); New Orleans, Louisiana (where the External Tank is produced and tested); Promontory, Utah (where the SRM is assembled and tested); and Titusville and Cocoa Beach, Florida, and VAFB, California (the two launch and landing sites for the Space Shuttle, respectively).

The operational phase of the Space Shuttle Program is scheduled to begin in 1980, when the Space Shuttle is expected to begin replacing a large share of the expendable vehicle flights. Except for the large changes which took place when the Apollo Program was completed, it has been possible to reassign most contractor and government personnel to new aerospace activities when NASA programs have been phased down. Currently, many expendable launch vehicle contractors are involved in the Space Shuttle Program, and it is expected that the increased level of space operations made possible by the Space Shuttle will result in the reassignment of many of these workers to Shuttle payload-related activities. In some cases, personnel may seek employment in nonspace-related areas, primarily because of a desire not to relocate.

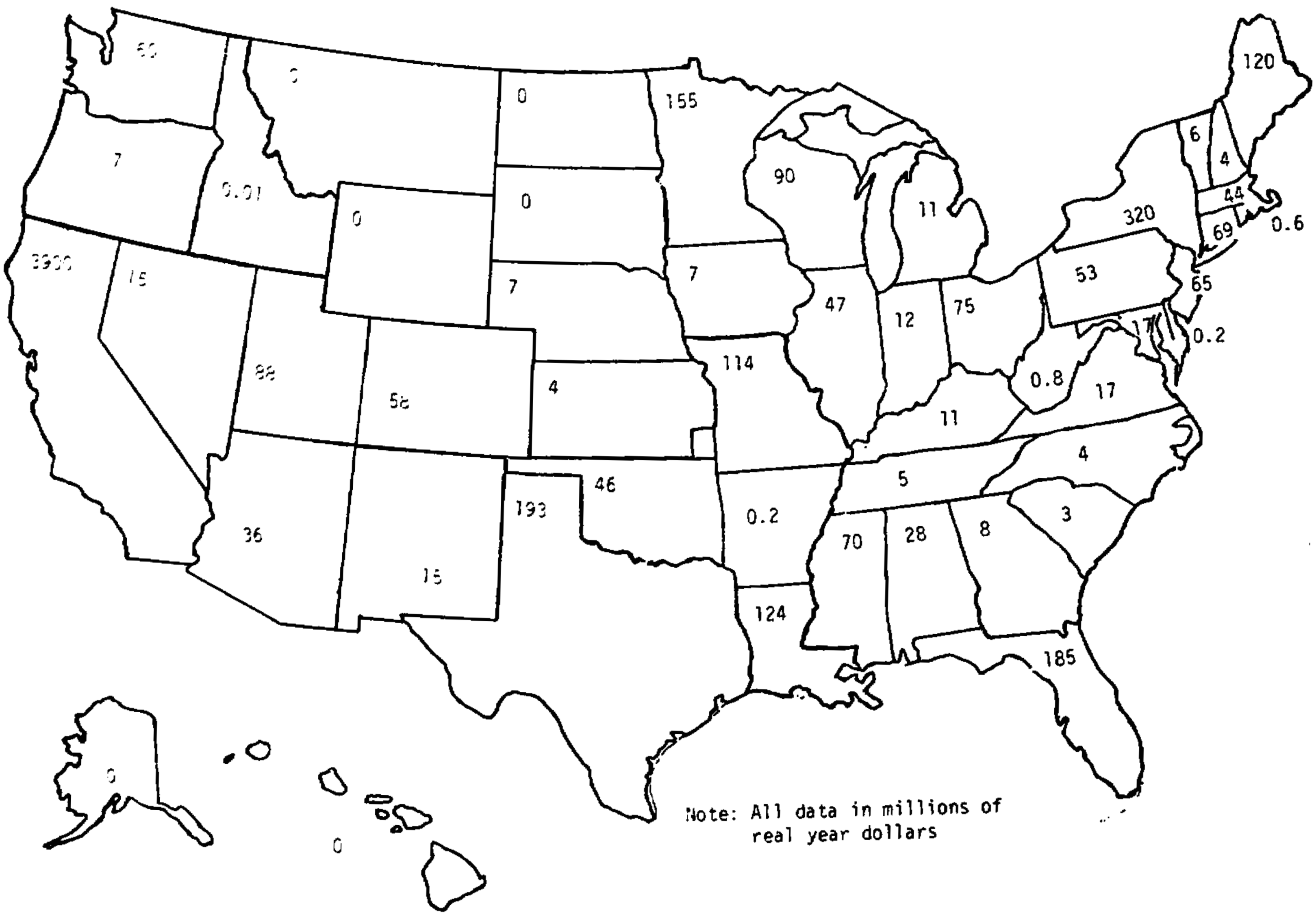

Figure 4-15.-- Nationwide distribution of Space Shuttle Program spending.

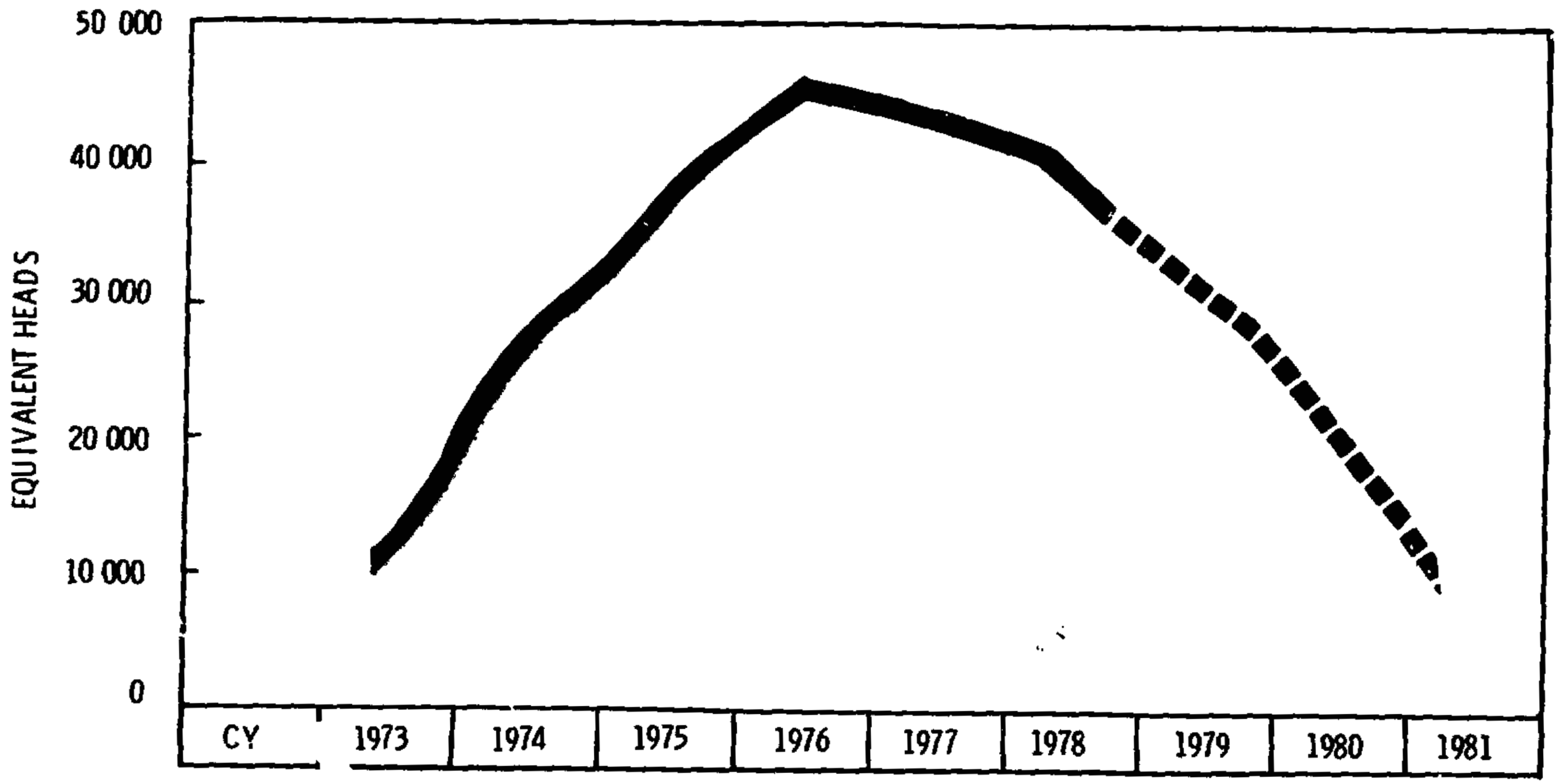

Figure 4-16.-- Manpower requirements for the development phase of the Space Shuttle Program.

The following paragraphs provide details of the demographic impact of the development phase at the major sites of Space Shuttle activity.

4.7.2.1 Orbiter Manufacture at Downey and Palmdale, California

The Rockwell plant at Downey produces Space Shuttle Orbiter subassemblies. It is closely associated with the Rockwell plant at Palmdale, where the Orbiter is assembled. The distribution of the work force between these two plants varies with program needs. In 1976, the total work force comprised about 8000 people, with about 5000 assigned to Downey and 3000 to Palmdale. It is expected that the number of people working on the Space Shuttle Orbiter project at both plants will decrease substantially by 1982, when all the Orbiter vehicles are completed.

Downey, California, is part of the Los Angeles metropolitan complex. The population of Downey is relatively stable, increasing from 86 000 in 1960 to 90 365 in 1976. This fact reflects that most of the available land has been occupied for some time. Downey presents a well-diversified occupational pattern, including construction, manufacturing, utilities, trade, finance, services, and government. In 1973, 40 595 residents of Downey were employed, with manufacturing firms (12 543 employees) and retail and wholesale trade (10 277 employees) being the principal employers. The Rockwell plant at Downey represents 10 to 15 percent of the total employment in Downey; however, when one includes the surrounding Los Angeles metropolitan complex, the percentage drops to a very small level.

Palmdale is 100 km (60 miles) north of the Los Angeles Civic Center. The Palmdale and associated Lancaster labor market area has grown steadily in population, increasing about 30 percent since 1962. In 1970, the Palmdale area had a total population of 82 733, with a total employment of 26 300 distributed among jobs related to agriculture, construction, manufacturing, trade, finance, services, and government. Manufacturing is the largest source of employment, and Lockheed Aircraft Corporation is the largest single employer (Lockheed had 7000 employees on its payroll in 1973). The number of employees at the Rockwell-Palmdale Orbiter plant reached a peak of nearly 3000 during 1976.

4.7.2.2 Main Engine Tests at Santa Susana and Bay St. Louis

Tests of the individual main engines are conducted at the Rocketdyne facilities near Santa Susana, California. Single-engine and engine cluster tests will be conducted at the NSTL.

The Bay St. Louis, Mississippi, area where the NSTL is located has grown steadily in population from 14 039 in 1960 to 21 200 in 1976. This increase occurred in spite of a lull in NASA activities after completion of the Apollo Program and reflects a diversified economy not overly dependent on NASA contract activity. The testing phase of the main engine will temporarily increase the work force in this area by about 1000.

4.7.2.3 SRM Development and Testing at Promontory, Utah

A manpower need of approximately 500, including direct and indirect support, is anticipated for SRM processing and testing at Thiokol. This number represents approximately one-fifth of the total employment at Thiokol/Wasatch. This represents continuity of employment because these positions are available as other programs are phased out.

Because Thiokol is the largest employer in the area, the continuity of employment for these predominantly skilled and professional workers contributes to the economic stability of the area. Should Thiokol/Wasatch be chosen as the supplier of the SRM for the operational phase of the Space Shuttle, these employment levels would continue and may slightly increase during the program.

Space Shuttle SRM program activities at Thiokol will have no direct effect on farming in the surrounding area. Grazing rights will be maintained; no additional lands are required. Continuity of employment levels minimizes any economic effects to farm families and to families with externally employed heads-of-households, whether they are directly, indirectly, or not at all connected with Thiokol/Wasatch.

4.7.2.4 Launch and Landing at Kennedy and Vandenberg

Most of the Space Shuttle flights will be conducted out of KSC, beginning in 1979. The Brevard County area surrounding KSC includes the towns of Cocoa Beach and Titusville. The population of this area increased rapidly when the space program was initiated -- from 111 435 in 1960 to 230 006 in 1970. Since the termination of the Apollo Program, the population has increased more slowly, with the 1975 population of 251 986. Employment in 1974 totaled about 95 000 with about 19 000 employed in various technical areas, including support contractors to KSC (currently totaling about 6000). Space Shuttle operations will lead to an increase in the number of employed persons in this area, but not by more than a few thousand.

The Space Shuttle flights will be conducted at VAFB starting in 1982. The major population centers around VAFB are Lompoc and Santa Maria. Lompoc had a population of 14 415 in 1960, which increased to 25 400 in 1976. The major activities are agriculture (large seed-growing farms) and support to VAFB. These activities employ estimated totals of about 4000 workers each. Santa Maria and its suburbs have a total population of 112 620 (1975), of which 8435 were employed in support of VAFB. Other employment amounted to 41 700. Space Shuttle operations at VAFB will employ 2000 to 3000 people. However, it is estimated that only 20 percent of these will be new employees. Existing manpower associated with expendable launch vehicle programs will satisfy the bulk of the Space Shuttle manpower requirements.

4.7.3 Historical, Archeological, and Recreational Factors

At some of the sites of Space Shuttle activity, features of historical, archeological, or recreational interest exist; the possible effects of Space Shuttle activities upon these features have been considered.

When Space Shuttle activities might destroy, damage, or interfere with sites of historical or archeological interest, precautions were (or will be) taken to mitigate the anticipated effect. Details of these effects and the mitigation actions are described in the appropriate site-specific environmental impact statements and summarized in the following sections.

No changes in existing recreational activities permitted on NASA-, USAF-, or contractor-owned lands are anticipated to result from the Space Shuttle Program. These include hunting, fishing, boating, skiing, camping, hiking, or similar activities. Restrictions and controls now in force at these facilities will not be changed for the requirements of Space Shuttle. In some locations, extensions of existing regulations will be maintained to support Shuttle requirements following the phasedown of earlier similar activities at particular facilities.

4.7.3.1 Palmdale and Edwards Air Force Base, California

Before construction of the necessary roadway to permit the overland transport of the Space Shuttle Orbiters from Palmdale to DFRC/EAFB, 13 sites in the construction area were surveyed to determine the extent of their historic or prehistoric interest. All were found to be minor in nature and deemed ineligible for inclusion in the National Register of Historic Places. Seven sites were free of the right-of-way and would be unaffected by the activity; six sites were on the right-of-way. In accordance with recommendations of the archeological report and the state coordinator for historic preservation, cultural materials and data were gathered and evaluated by a qualified archeologist at the six sites on the right-of-way prior to grading operations (ref. 1-3).

During the data collection phase but after publication of the environmental impact statement, materials recovered at one of the sites were found to be more significant than expected; and the site was then designated as being eligible for inclusion in the National Register of Historic Places. Although it was not possible to relocate the roadway sufficiently to avoid the site, a number of construction modifications were undertaken to protect the site from damage (ref. 4-55). Because of these mitigative actions, the U.S. Army Corps of Engineers, in consultation with the state historic preservation officer, issued a memorandum stating that no adverse effect resulted (refs. 4-55 and 4-56); and the Advisory Council on Historic Preservation (ref. 4-57) approved the memorandum.

4.7.3.2 Santa Susana, California

Indian caves are located on the property of USAF Plant 57 at Santa Susana, California, the site of component and subsystems integration tests of the Space Shuttle's main engines. No adverse effects upon these caves are expected from the noise or the ground vibration resulting from these tests (ref. 1-2).

4.7.3.3 Promontory, Utah

Two historic sites listed in the National Register of Historic Places are located near Promontory, Utah, where the SRM is being manufactured and tested: the Methodist/Episcopal Church in Corinne and the Golden Spike National Historic Site at Promontory Point. No adverse effect on these sites or on any known archeological sites is anticipated by Space Shuttle Program actions (ref. 1-6).

This general vicinity, near the Great Salt Lake and adjacent to the Wasatch Mountains, is an area of extensive conservation efforts and recreational activities. The former includes the Bear River Migratory Bird Refuge, administered by the U.S. Fish and Wildlife Service; the latter includes hunting, fishing, skiing, and other outdoor sports. Possible effects caused by SRM processing and test activities at Thiokol on the Refuge or other managed wildlife areas and on recreational activities were studied (ref. 1-6), and no effects of significance were noted.

4.7.3.4 Bay St. Louis, Mississippi

The NSTL is located in Hancock County, Mississippi, near the town of Bay St. Louis. The area abounds in fish and wildlife. Much of the Federal property remains in essentially virgin condition, and a wildlife management plan is in force to protect and conserve the many species (see ref. 1-4). Outside the Federal area, a buffer zone is maintained in which no residences or industries are permitted because of its proximity to the sources of noise generated by rocket tests. Most of this buffer zone is privately owned but unimproved; temporary occupancy for hunting or fishing purposes is permitted here.

No major facility construction or alterations are planned for the Space Shuttle Program; thus, no adverse effects to any historical/archeological resources are anticipated. The facility will continue to operate under its current land management plan.

4.7.3.5 Launch Facilities at Kennedy Space Center, Florida

Space Launch Complex 39, the launchsite for the Apollo missions, Skylab orbital missions, and the U.S. Apollo launch for the Apollo-Soyuz Test Project, will be the launch complex for Space Shuttle launches from the eastern United States. This launch complex is listed in the National Register of Historic Places. Because it is necessary to modify the launch complex to accommodate the Space Shuttle, NASA and Florida's historic preservation officer, with the approval of the Advisory Council on Historic Preservation, entered into a memorandum of agreement (in accordance with the National Historical Preservation Act) that any adverse effects would be satisfactorily mitigated (ref. 4-58).

KSC is also the site of the Merritt Island Wildlife Refuge, and the boundaries of the two are common. Under an agreement between NASA and the Bureau of Sport Fisheries and Wildlife, the Bureau (subject to certain conditions) exercises primary administration over all property (except the

space program's facilities) for all purposes unrelated to the space program. These purposes include the conservation of wildlife, fish, and game; recreation and education; outleasing of orange groves, fish camps, and aviaries; and the management of Playalinda Beach (ref. 1-5).

Construction activities for the Space Shuttle Program at KSC are primarily confined to areas previously used for industrial activities and are having little or no adverse effect on the Refuge. The single, most extensive construction in terms of land area was the construction of the Landing, Deservicing, and Safing Facility, which included a 4600-m (15 000-ft) long runway and associated apron and tow way. This facility altered approximately 546 hectares (1350 acres) from its status as part of the Refuge to program use. Vegetation and wildlife were displaced. Great care was taken to protect wildlife during the construction, including the careful removal of large species (such as alligators) from the construction site to prevent their injury or destruction. Dredging of the existing barge canals are not expected to have any adverse impacts on historical, archeological or recreational resources.

KSC areas currently used for recreation will continue to be accessible to the general public in a manner similar to that during the Saturn-Apollo launch operations. When the Space Shuttle becomes operational, access to the Refuge and beach areas will be prohibited for only a relatively short period immediately prior to launch when the vehicle is on the pad.

During development and testing, State Route 402, which is the present access to Playalinda Beach, will be closed for a period of up to 30 days. During the launch of certain space vehicles, safety and security measures have historically required closure of Playalinda Beach for periods of up to 4 months. The NASA safety and security measures are designed to cope with covert/overt penetrations and to prevent damage to flight hardware and to launch support facilities. The period of closure associated with the Space Shuttle depends on the assessment of alternatives for the Canaveral National Seashore (ref. 10-4). This could result in closure of the entire Playalinda Beach or only of its southern portion up to 35 percent of the time during the operational phase of the Space Shuttle.

A National Park Service study of all coastlines along the Atlantic Ocean and the Gulf of Mexico identified the Cape Canaveral and Mosquito Lagoon region as one of the prime remaining areas for providing public seashore recreational opportunities. Public Law 93-626 established the Canaveral National Seashore, which will include some 27 068 hectares (67 000 acres).

Under agreement with the U.S. Fish and Wildlife Service, the boundaries of the Merritt Wildlife Refuge and KSC are coextensive. This agreement provides that the U.S. Fish and Wildlife Service, subject to enumerated conditions, shall have primary administration over all property not related to the space program. In addition, 16 592 hectares (41 000 acres) of submerged and fast land owned outright by or otherwise obligated to NASA for operation of KSC are encompassed in the Canaveral National Seashore. Of these 16 592 hectares, 2693 hectares (6655 acres) are part of the national seashore administered by the National Park Service; and 13 899 hectares (34 345 acres) are part of th Merritt Island National Wildlife Refuge.

4.7.3.6 Launch Facilities at Vandenberg Air Force Base, California

Several sites of archeological interest may be adversely affected by construction activities at VAFB (ref. 1-9). To the extent possible, these adverse effects will be mitigated, and the USAF will consult with the historic preservation officer of the State of California and the Advisory Council on Historic Preservation as required by law.

Extensive recreational facilities exist in the VAFB vicinity (see ref. 1-9). For public safety, it is sometimes necessary to close one or more of three near-by parks when missile launches are scheduled. It is anticipated that the period of closure would be no more than 1 day.

5. ALTERNATIVES

Alternatives to the baseline Space Shuttle design and operations are discussed in this section. The baseline Space Shuttle is the result of considering trade-offs in performance, time, cost, reliability, technology, and environmental consequences. Environmental issues are continually being reevaluated; as new data and technology arise, design and operations trade-offs are reconsidered. Although current data indicate that the Space Shuttle is "environmentally sound," several alternatives are currently under investigation. Each of these alternatives, while reducing a particular environmental concern, must be evaluated against increased cost, decreased performance, decreased benefits, and the introduction of new environmental problems.

In the 1972 environmental impact statement for the Space Shuttle Program (ref. 1-1), three alternatives were discussed: the development of a fully reusable two-stage hydrogen/oxygen fueled shuttle, the use of liquid boosters, and the continued use of expendable launch vehicles.

Section 5.1 presents background information on how the current Space Shuttle design evolved from the considerations of alternatives. Sections 5.2 through 5.4 present alternate booster designs (solid and liquid), alternate ground operations (ground cloud neutralization and new closed-loop cleaning system for Freon-113), and the continued use of expendable vehicles.

Each site-specific environmental impact statement has considered various alternatives. No attempt has been made in this discussion to include these alternatives. The reader is referred to references 1-2 through 1-9 for a review of site-specific alternatives.

5.1 Background

The design concept to which the studies initiated in 1970 were originally addressed described a very large, fully reusable system consisting of piloted boosters and a piloted orbiter stage (similar to, but larger than, the current Orbiter). Development of this concept would have required major technological advances with significant technical risks; the development cost of such a system (excluding facilities) would have been more than $10 billion (1971 dollars).

Environmental effects of this system on air quality would have been quite small, as noted in the first environmental impact statement draft released in March 1971. The hydrogen/oxygen propellant mixture burns cleanly to produce only water vapor. During ascent, such a system would have imposed sonic boom overpressures equal to or greater than those expected from the currently proposed system. Booster return overpressures might have been reduced by booster maneuverability; Orbiter overpressures during reentry would have been higher because of its larger size. No External Tanks would have been utilized; therefore, the controlled entry of such tanks would not have been considered.

The high total development cost and technical risks implied annual development costs as high as $2 billion during the later 1970's. Studies were thus initiated (in 1971) to determine whether other designs could provide a lower development cost and a lower technical risk.

Studies initially following those of the two-stage flyback concept showed that the size of the system and its development cost could be greatly reduced through the use of an external, expendable liquid hydrogen tank for the Orbiter vehicle with a small increase in operating costs. Further study showed that additional cost savings and technical advantages in the development program would accrue if both the liquid oxygen and liquid hydrogen for the Orbiter were carried in an expendable External Tank. This change permitted the Orbiter vehicle to be significantly smaller, thereby simplifying development and reducing substantially the development and procurement costs at the expense of some additional increase in the recurring cost per flight.

With these modifications, Space Shuttle development costs were estimated to be between $7 and $8 billion (1971 dollars). Environmental impact would have been essentially the same as that of the more expensive, initial two-stage flyback concept, except for the new element of having to dispose of an expendable hydrogen/oxygen propellant tank from orbit. It was determined that the tank could be equipped for controlled reentry to a remote ocean area and that no significant environmental hazard would result.

In 1971-72, additional studies indicated that Space Shuttle development costs could be reduced to about $5 billion (1971 dollars) only at the expense of compromising the objectives of providing a new flexible orbital capability at low operational costs. Thus, attention was turned toward reducing development costs of the booster. Consideration of a smaller orbiter with a side-mounted external propellant tank allowed the possibility that two unmanned boosters could be effectively employed. The unmanned boosters studied included both liquid and solid propellant boosters.

It was then determined that a solid booster would result in lower development costs, less capital risk per flight, and lower technical risk of development than the liquid boosters. Environmental effects of the solid booster were shown to be minor, although somewhat greater than those of the liquid system. These factors led to the selection of the SRM booster concept for the Space Shuttle. This concept was evaluated in the 1972 environmental impact statement for the Space Shuttle Program (ref. 1-1).

5.2 Alternate Booster Designs

After the selection of ammonium perchlorate-based propellant for the solid booster, the chlorine catalytic cycle, leading to the destruction of stratospheric ozone, was discovered (ref. 5-1). Simultaneously, as efforts to reevaluate the environmental impact of the perchlorate-based propellant began, the issue of ozone depletion caused by chlorofluoromethanes (Freons from aerosol spray cans) was raised (ref. 5-2). Since the basic chemistry

is the same, the results of these two studies became mutually supportive, leading to a fairly thorough investigation of the effects of chlorine in the stratosphere. The conclusions reached to date indicate that the effects of the perchlorate-based propellant are many times lower than the effects of the chlorofluoromethanes (refs. 4-19 and D-4).

As a result of concern over stratospheric ozone depletion caused by the Space Shuttle's booster, alternate booster designs were again considered. A cleaner propellant can be obtained by either a change to the use of a low-chlorine solid propellant or the use of liquid propellant boosters.

5.2.1 Solid Propellants

A study of low-chlorine solid propellants was initiated in August 1974 to define possible alternates to the baseline propellant. Complete replacement of the perchlorate propellant with a nitrate-based propellant leads to unacceptable vehicle performance. Consequently, a composite propellant grain was considered in which the baseline propellant is burned to an altitude of up to 20 km (63 000 ft). Then, the burn changes to an alternate low-chlorine formulation for passage through the stratosphere.

Approximately 250 different possible alternate propellant formulations were evaluated. These formulations included various combinations of ammonium perchlorate and other oxidizers that do not produce hydrogen chloride, such as ammonium nitrate, cyclotetramethylenetetramine (HMX), trimethylethanetrinitrate, nitrocellulose, nitroglycerine, and cyclotri methylenetrinitramine (RDX). Formulations were first evaluated on a theoretical basis in comparison with the baseline propellant. From this comparison, the most promising alternate propellant formulations were selected for preliminary process, compatibility, hazard, burn rate, pressure exponent, and density impulse characterization. Based on results from these characterizations, the best HMX and non-HMX containing alternate propellant formulations were selected for testing. Propellant formulations, properties, and exhaust compositions of these two alternate formulations ("A" and "B") are compared with the baseline formulation in table 5-1. To achieve acceptable properties, both alternate formulations require the addition of ammonium perchlorate. The theoretical exhaust composition for the baseline and alternates "A" and "B" assumes no afterburning (ref. 4-20).

Use of an alternate propellant would lead to a performance loss estimate at about 3 percent for the entire grain (25 percent of the grain consists of propellants having about 10 percent less specific impulse). This corresponds to a loss of payload capacity in the range of 900 to 2300 kg (2000 to 5000 lb).

New manufacturing processes and techniques would need to be developed for employing the alternate propellant in the SRM; furthermore, the alternate propellant composition is more costly than the baseline composition. Development costs for using alternate propellants in the SRM have been estimated at a minimum of $120 million and as high as $500 million (1976 dollars). Assuming that the alternate solid propellant is phased into the Space Shuttle Program in 1983, an additional cost of $1.6 million per

TABLE 5-1.-- PROPELLANT FORMULATION, PROPERTY, AND EXHAUST GAS COMPOSITION DATA

Data	Propellant		
	Baseline	A	B
Propellant formulation (percent by mass):			
Ammonium perchlorate	70	10	10
Ammonium nitrate	--	44	61
Aluminum	16	15	15
HMX	--	17	--
Binder and additives	14	14	14
Physical property:			
Density, g/cm^3	1.77	1.65	1.65
Specific impulse, sec	2584	2375	2273
Exhaust gas composition:			
Hydrogen chloride	20.9	3.1	3.1
Hydrogen	2.1	3.7	2.9
Water	9.4	6.1	16.2
Carbon monoxide	24.1	31.8	19.6
Carbon dioxide	3.5	3.8	6.5
Nitrogen	8.7	22.9	23.2
Aluminum oxide	30.2	28.2	28.3
Other	1.1	0.4	0.2

flight or an additional program cost of \$0.8 billion is estimated. The alternate would reduce (not eliminate) ozone depletion by a factor in the range of 2.5 to 5, but tropospheric effects would remain unchanged. Thus, because of high cost, loss in performance, inability to reduce the effects in the troposphere, and minimal amount of ozone reduction by the baseline, the alternate solid propellant is not desirable.

5.2.2 Liquid Propellants

A liquid propellant booster would provide cleaner combustion in both the ground cloud and the stratosphere. A study on using a liquid propellant booster that would provide 50 percent more Space Shuttle payload has been completed (ref. 5-3). This booster would burn kerosene with liquid oxygen. The products of combustion would be mainly water and carbon dioxide. According to this preliminary study, R&D cost for this booster is about \$1.5 billion (1975 dollars). However, if it is assumed that the experience gained by using the solids is applied to liquid designs and that the liquids are phased into the Space Shuttle Program in 1985, then the cost per launch of the liquids could be about \$1 million less than the cost per launch of the solids, assuming that full recovery and reuse are achieved. If the increased payload capability of the liquid booster were used, the savings could be much greater.

Because of the potential to eliminate the ground cloud and stratospheric effects and with the increased payload capability and launch cost savings, this alternative is attractive. However, technical risks related to recovery and reuse, coupled with the estimated \$1.5 billion development cost, make this alternative unacceptable at this time. However, it does constitute an option for later growth versions of the Space Shuttle.

5.3 Alternate Operations

5.3.1 Ground Cloud Neutralization of Hydrogen Chloride

Potential adverse environmental effects associated with hydrogen chloride in the Space Shuttle exhaust cloud might be reduced by the use of a system for neutralizing the hydrogen chloride. A study to determine the feasibility of chemically neutralizing the cloud was initiated in 1975. The results of this study (refs. 4-2 and 5-4) indicate that several chemicals could be used. The study showed that the delivery of the neutralizing agent into the Shuttle exhaust cloud could be carried out during the formation of the cloud with equipment located on the ground and in the air.

For the ground-based system, delivery rates need to be such that all of the required neutralizing agent (sodium carbonate solution) is injected within a period of 10 sec. The delivery of a neutralizing agent by the airborne system needs to be accomplished as soon as possible after the launch. The only feasible neutralizing agent found for airborne delivery was ammonia.

Neutralization of the cloud by these two chemicals would replace most of the hydrogen chloride with the products of the neutralization reactions; namely, sodium chloride (salt) and ammonium chloride. However, some unreacted hydrogen chloride, sodium carbonate, and ammonia would still be expected to be part of the cloud. In addition, the cooling effect of the evaporating water would suppress the afterburning of the exhaust, reduce the cloud rise, and increase the aluminum oxide, chlorine, and carbon monoxide ground level concentrations (refs. 4-2 and 5-4). Thus, while the amount of hydrogen chloride in the cloud could be significantly reduced, the levels of other chemicals would be increased.

Little data are available on the environmental consequences of these chemicals. The data available suggest that the effects will range from retarded growth of some plants exposed to salt to fertilization of plants exposed to ammonium chloride. For a complete understanding of the environmental consequences of the total mixture of chemicals, a level of experimental effort similar to that carried out for hydrogen chloride alone is required.

The estimated cost of installing the recommended neutralization delivery systems is about $400 000 (1976 dollars), and the cost of chemicals per launch would be about $5000. Because of this cost, the uncertainty in environmental consequences of neutralization and the fact that the ground cloud can be controlled by choice of meteorological conditions (ref. 4-2), the current plan is not to exercise the option of neutralization.

5.3.2 Recovery System for Freon-113

Recovery of Freon-113 is a proven concept contributing to the reduction of emissions to the atmosphere. Significant reductions in the loss rate of Freon-113 during cleaning operations at the launch can be achieved by using closed-loop systems and recovery techniques to purify and reuse contaminated Freon-113. Three systems are involved in the current launchsite operation:

1. The launchsite cleaning laboratory uses Freon-113 to clean components removed from propellant handling systems at the launch pad. A system which reclaims approximately 63 kg (139 lb) per hour of the Freon-113 used in cleaning operations has been in use since the Apollo Program to recover Freon-113 at a low-volume rate.

2. To reduce the loss of Freon-113 in the cleaning laboratory, a system has been designed to reduce emissions to the air resulting directly from the cleaning operations. Freon vapor will be reclaimed at a rate of 1265 kg (2782 lb) per month from the air in the cleaning laboratory, beginning in 1979.

3. A construction project to provide a Freon reclamation facility capable of processing much larger quantities of Freon-113 is now under consideration. Use rates for the Space Shuttle Program will be larger than for prior systems, especially for the flush of launch pad oxidizer

systems. These uses will exceed the capacity of the cleaning laboratory reclamation system by a large amount. The system is proposed in the 1979 construction and facilities budget as a separate line item.

5.4 Continued Use of Expendable Launch Vehicles in the 1980's

This section considers the continued use of expendable launch vehicles resulting from the postponement or cancellation of the Space Shuttle Program.

The Space Shuttle was originally justified as being a less expensive method of continued space activities (refs. 5-5 to 5-7). Current analyses continue to illustrate this savings. Using the October 1973 Space Shuttle traffic model (ref. 5-8), an expendable launch vehicle traffic model was developed, using the ground rule that the payloads of each model provide equivalent scientific returns (ref. 5-9). The results showed that there was a $14.1 billion savings (FY 1973 dollars) by using the Space Shuttle during its planned 12-year period (refs. 5-10 and 4-54).

The expendable launch vehicles which were assumed to be replaced by the Space Shuttle are the Scout, Delta, and Titan-III boosters, with a wide variety of types of upper stages. The Atlas/Centaur was not cost effective in this study. With this launch fleet and traffic model, the effects on the environment by postponement or cancellation of the Space Shuttle Program would be the following:

1. A factor of 10 less hydrogen chloride would be emitted below a 500-m (1640-ft) altitude. The reductions in hydrogen chloride emission arise from the facts that Space Shuttle payloads would be heavier but less costly than those of expendable launch vehicles. Also, for each Shuttle launch, the Orbiter must be placed in orbit.

2. A factor of 5 less hydrogen chloride would be emitted in the stratosphere. The reduction in hydrogen chloride emission for the expendable launch vehicle program is a result of the additional weight that the Shuttle carries to orbit, as noted above.

3. A factor of 4 more toxic fuels (hydrazine, nitrogen tetroxide, and nitric acid) would be used. Nearly all the thrust for the Shuttle vehicle is provided by liquid hydrogen, liquid oxygen, and solid propellant rocket fuels, thereby minimizing the use of more toxic fuels.

4. Launch sonic booms would be less intense. The size of the expendable launch vehicles is generally smaller than the Space Shuttle, leading to a smaller amplitude of launch sonic boom.

Reentry control of expended spacecraft and upper stages that would be left in orbit is not considered technically feasible, even at greatly increased costs. Thus, the natural decay and reentry of this material would add the following environmental consequences to using expendable vehicles: Reentry sonic booms would be more frequent but less intense and would occur over more varied locations; and the probability of damage resulting from the reentry of orbital debris would be increased.

The Space Shuttle represents a cost-effective and flexible method of conducting space activities, which will benefit people and the environment (see sections 7 and 9). Following these goals, NASA is committed to continuing to develop and operate the Space Shuttle system. Environmental advantages and disadvantages of an expendable versus a reusable (Space Shuttle) STS are not clear. Therefore, postponement or cancellation of the Space Shuttle Program in favor of the continued use of expendable launch vehicles is not considered advantageous from an environmental viewpoint.

6. POTENTIAL UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

The following potential adverse environmental impacts are associated with the proposed action. Unavoidable impacts which are minor or less important are discussed in section 4.

6.1 Air Quality of the Lower Atmosphere

The exhaust products from the SRB for the Space Shuttle include hydrogen chloride, nitrogen oxides, chlorine, carbon monoxide, and aluminum oxide. The hot exhaust cloud rises quickly to altitudes ranging from 0.7 to 3 km (0.4 to 1.8 miles) and then drifts and disperses with the prevailing wind. The result is a temporary and localized degradation of air quality in regions over which the cloud passes. Surface concentrations of the exhaust products are not expected to exceed the allowable limits for human beings, wildlife, or plants. Under unusual atmospheric conditions, the cloud may be trapped in an inversion layer, which prevents it from dispersing rapidly.

Meteorological conditions for the test or launch will be selected to mitigate the potential surface effects. In addition, a long-term monitoring program of the launch areas will be maintained to verify the expected absence of ecological effects.

Air space near the launch operations area will be controlled to exclude aircraft flying at low altitudes when meteorological conditions might produce a "trapped" cloud.

Raindrops which fall through the exhaust cloud will absorb hydrogen chloride to produce acidic rain. The acidity is highest at the beginning of rainfall through the cloud and less as hydrogen chloride is washed out of the cloud. Near the launch area, the initial rain acidity can correspond to pH values near 1, which might temporarily damage vegetation. Outside the launch area, the initial rain is less acidic, and damage to vegetation is less likely. In any case, the effect is highly localized and temporary. Meteorological conditions for the test or launch will be selected to minimize acidic rain effects.

It is not possible now to predict what effects, if any, the Shuttle exhaust cloud might have on the weather. Insufficient information is available to evaluate completely this potential effect, but if any effect does occur, it would be limited in size and duration. Research is continuing on this area. Appropriate meteorological conditions for launch would be selected, should further studies indicate the possibility of any significant effects.

6.2 Air Quality of the Stratosphere

Passage of the Space Shuttle through the stratosphere introduces chlorine compounds into the ozone layer. This induces a decrease in the ozone level. The mean reduction is estimated to be about 0.25 percent

when the Space Shuttle is fully operational at 60 launches per year. This result has been supported by the NAS (ref. 4-19). The NAS conclusions were

> ... that the combustion products from the Space Shuttle at the presently planned launch schedule of 50 per year will make a small contribution (~0.15 percent with a range of 0.05 to 0.45 percent) to the total reduction of stratospheric ozone by human activities. Furthermore, since these products are injected directly into the stratosphere, their atmospheric residence time is relatively short, so there would not be long lasting aftereffects should the program be terminated.

A 0.25-percent ozone reduction would result in about a 0.5-percent increase in ultraviolet radiation at the surface of the Earth. The consequences of this increase on agriculture, ecology, and climate are considered insignificant. Based on the limited available biological data, the effect on nonmelanoma skin cancer cannot be satisfactorily predicted for this small change. There is no conclusive evidence that a change in the incidence of melanoma skin cancer would result.

6.3 Noise

Test firings and launch will subject large areas to moderate sound levels of predominantly low frequencies for 1 to 2 min. At launch, the peak A-weighted sound pressure levels at the nearest-to-pad boundary at KSC is expected to be about 80 dB(A) and about 90 dB(A) at VAFB. The peak level at the KSC viewing stand will be about 95 dB(A).

During engine tests, the peak A-weighted sound pressure levels to which the public might be exposed are about 95 dB(A) for the SRM tests and 85 dB(A) for the main engine tests.

The A-weighted 24-hour average sound levels (Leq) to which the public would be exposed for engine tests or launches are all less than the EPA daytime guideline value of 70 dB(A). Consequently, no effects on the health of human beings are expected from this noise. Similarly, no effects on wildlife are expected. Any cumulative effects of noise in the launch areas would be detected by the ecological monitoring program. The low frequency sound may briefly rattle loose windows in structures near the launch and test areas.

6.4 Sonic Boom

Sonic boom will be produced both during launch and reentry. The launch boom is about 300 N/m^2 (6 psf) over a wide area of the ocean, with a narrow region a few hundred meters wide where the boom is focused to levels that may reach 1500 N/m^2 (30 psf). The reentry boom from the Orbiter reaches a maximum value of 101 N/m^2 (2.1 psf).

The launch boom is larger than the Orbiter's reentry boom because the launch vehicle and its exhaust plume are physically larger than the Orbiter. The launch boom occurs entirely over the Atlantic Ocean for launches at KSC and does not produce any significant environmental impact. The launch booms from VAFB occur over the Pacific Ocean. Some launch trajectories from VAFB may produce booms which reach the offshore Channel Islands. The infrequent occurrence of sonic booms on these uninhabited islands is not expected to produce significant environmental effects.

The reentry booms will occur over populated areas of Florida and California. The low intensity of these booms -- maximum of 101 N/m^2 (2.1 psf) -- is not expected to produce any effect other than a slight startle reaction in about half the people who hear the boom. The relatively long duration of the pressure wave associated with sonic booms may rattle loose windows.

7. RELATIONSHIPS BETWEEN THE SHORT-TERM USES AND THE LONG-TERM MAINTENANCE AND ENHANCEMENT OF THE ENVIRONMENT

Sections 4 and 6 discuss short- and long-term environmental effects (or uses) of the Space Shuttle Program. Briefly, the short-term effects of the environment, such as air pollution and noise caused by the Space Shuttle, are localized and of relatively short duration. The only apparent long-term adverse effect relates to a predicted reduction of the ozone layer by 0.25 percent; and even then, it is not permanent, as the recovery period is estimated to be 2 to 6 years. On the other hand, the Space Shuttle will provide a great potential for maintaining and enhancing man's environment on Earth. The following paragraphs discuss direct and indirect environmental benefits that are expected to result from the Space Shuttle Program and its related space activities. Benefits other than those mentioned below are discussed in section 9.

The Space Shuttle will provide for the delivery to space and subsequent use of three classes of payloads: Earth observation equipment positioned in the cargo bay of the Space Shuttle Orbiter, Earth observation satellites, and space laboratories (Spacelab and Space Station). These payloads expected to be launched in the 1980's will provide capabilities that will allow monitoring predictions of change, management, and enhancement of the Earth's environment. Approximately 15 percent of all Shuttle payloads are expected to offer direct environmental benefits. Examples of these benefits are discussed below.

- Land use and land mapping: Benefits in this area include the preparation of current maps prepared in a matter of days compared to the months or even years previously required; a supply of data for comprehensive regional land-utilization planning; and development of thematic maps (e.g., previously unknown features in Antarctica have been identified, including a group of mountains in Southern Victoria Land and at the heart of Lambert Glacier).

- Biological resource management: Earth observation satellites will also aid in the management of biological resources. Accurate surveys of timberland are difficult, if not impossible, to achieve because most forests are located in remote areas. Observation from space allows instantaneous identification of timber types, disease, yield, and the existence of forest fires. Agricultural crop data around the world can be unreliable and sometimes nonexistent. Space crews, working with remote sensing equipment, can identify crops and acreage; discern the vigor of the crop, any diseases, or pests; and estimate the yield per acre. Many diseases can be spotted before the farmer even knows that he has a problem. In a world where hunger and malnutrition continue to be problems, such information becomes extremely vital. Earth observations from space will allow improved management of fishing resources. Fishing experts will be able to predict fish movement throughout the Earth's waters.

- Mineral resource management: Geologists studying photographs of the Earth from space have found clues to the locations of new oilfields. From a space vantage point, promising sites for new petroleum, geothermal, and mineral deposits may be identified and onsite exploration guided.

- Water resource management: Earth observation satellites will allow the management of water resources in areas ecologically sensitive to water levels. From space, water patterns can be identified, the development of watersheds can be predicted, floods can be forecast, and crops and property can be protected.

- Pollution monitoring: Earth observation satellites launched by the Shuttle can survey strip mining activities; track air, water, and thermal pollution and identify its source; monitor air quality; monitor the stratospheric ozone layer; and locate oil slicks on the ocean's surface. A pollution-mapping satellite can cover the entire United States in about 500 photographs; cameras carried in high-altitude aircraft would use about 500 000 frames to cover the same area. It would take years to monitor by aircraft what can be monitored from space in a few days. In congested urban areas, pollution levels can be accurately predicted from space by monitoring local weather patterns and pollution sources.

- Weather observations and forecasts: Weather affects the lives of every person on Earth -- food supplies, travel, and recreation. Weather satellites currently allow advance planning and improve one's understanding of the weather environment. In the 1980's, advanced weather satellites launched by the Space Shuttle will improve the quality of weather forecasts. Improved disaster warning systems will also monitor hurricane, typhoon, tornado, and iceberg activity. These satellite systems will continue to provide the cornerstone of severe storm warnings. Warnings will allow ample time for the populace to prepare for emergencies and/or to evacuate the area. Satellites will also continue to assess damage caused by severe weather and will help determine the need for disaster relief.

- Earthquake prediction: Spaceborne systems carried aloft by the Space Shuttle will use lasers to measure minute shifts in the Earth's crust as a possible method of predicting earthquakes. It is likely that in the future, a significant number of lives may be saved as a result of earthquake prediction. Methods could also be developed to relieve stress in the Earth's crust and thus prevent earthquakes.

8. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The Space Shuttle Program requires the commitment of both natural and cultural resources. The commitment of natural resources includes the consumption of mineral and biological resources. The commitment of cultural resources includes human and land resources. Restrictions will be imposed on the use of some historical and recreational areas. These basic commitments are not different from those necessary for many other research and development programs; they are similar to the activities that have been carried out in previous space program activities over the past 18 years.

8.1 Natural Resources

Activities associated with the Space Shuttle Program will utilize and consume various quantities of materials and energy; and in some cases, a change in ecological resources may result. This section attempts to quantify, where possible, those natural resources which will be committed as a result of Space Shuttle Program activities.

8.1.1 *Material Requirements*

The various materials that will be required for the Space Shuttle Program can be divided into four general classes: materials for construction and use of facilities, materials for production and transport of Space Shuttle hardware, materials consumed during test programs, and materials consumed as a result of Space Shuttle launches. These requirements are discussed in sections 8.1.1.1 to 8.1.1.4. Section 8.1.1.5 summarizes the possible impacts resulting from material consumption during the Space Shuttle Program.

8.1.1.1 Construction and Use of Space Shuttle Facilities

The modification or construction of government or contractor facilities requires certain building materials. Most of the construction activities at contractor sites and NASA centers are nearing completion, but work has yet to begin at VAFB. Building materials such as steel, aluminum, concrete, blacktop, wood, and wire will be used. Depending upon the type and location, the operation and maintenance of Space Shuttle facilities will require materials such as natural gas, oil, coal, gasoline, diesel fuels, paper, water, paint, and cleaning agents.

8.1.1.2 Production and Transport of Space Shuttle Flight Hardware

Space Shuttle flight hardware consists of the Orbiter, the SRB, and the External Tank. The manufacture of these hardware items will require a modest amount of metals and other materials. The Orbiter will be constructed mostly out of aluminum, with various amounts of steel, copper, titanium, composite, and other materials. The Orbiter has an expected life of 100 flights before retirement; therefore, good utilization of

materials will result. The Orbiter's materials will probably never be reused or recycled, for the Orbiters will eventually become museum pieces. The SRB's will be made mostly of steel, with various amounts of aluminum, composite, insulation, and other materials (propellants are discussed separately below). The SRB case has an expected life of 20 flights. Steel from used cases will probably be recycled. The External Tank is made mostly of aluminum, with small amounts of steel, copper, and other materials. The External Tank will not be reused because it will be expended in the ocean during each Space Shuttle flight. Approximately 32 000 kg (71 000 lb) of material will be lost per flight with the loss of the External Tank.

The transportation of Space Shuttle hardware throughout the country will contribute to the consumption of fossil fuels. Space Shuttle hardware will require both ground and air transport, consuming gasoline, diesel fuel, and jet fuel. Transportation activities involving many of the Space Shuttle's components are considered routine. Unique transport activities are transporting the Orbiter piggyback on a Boeing 747, transporting SRM segments by rail, and transporting the External Tank by barge.

8.1.1.3 Space Shuttle Test Programs

During the development phase of the Space Shuttle Program, many tests must be performed to ensure proper hardware operation (see section 2.3.1). Tests of the Space Shuttle's main engine and the External Tank will involve the consumption of liquid hydrogen, oxygen, and nitrogen. Static test firings of the SRM and the separation motor will require the consumption of solid propellant ingredients such as aluminum powder, ammonium perchlorate, and PBAN binder. Nitrogen tetroxide and MMH will be required for the static test firings of both OMS and RCS rocket engines. Jet fuel will be expended while the ALT program (Boeing 747), crew training flights (Gulfstream-II), and SRB parachute testing (B-52) are being conducted.

8.1.1.4 Space Shuttle Launches

In the support of Space Shuttle launches from KSC and VAFB, solid and liquid propellants and other consumable fluids will be expended. Tables 8-1 and 8-2 indicate the average annual requirements for solid and liquid propellants and fluids. The major fluid substances consumed are liquid oxygen, liquid hydrogen, gaseous and liquid nitrogen, gaseous helium, MMH, hydrazine, nitrogen tetroxide, Freon-113, and isopropyl alcohol. Major solid propellant ingredients are ammonium perchlorate, aluminum powder, and PBAN binder.

8.1.1.5 Impact of Material Consumed to Support the Space Shuttle Program

Peak annual requirements for major materials used to support the Space Shuttle Program at a launch rate of 60 flights per year are compared to recent annual U.S. production data in table 8-3. The most significant impacts on material production are related to the manufacture of PBAN

TABLE 8-1.-- SPACE SHUTTLE FLIGHT PHASE LIQUID PROPELLANT AND OTHER FLUID REQUIREMENTS

(From reference 8-1)

Liquid propellant or fluid	Purpose	On board quantity, kg	Additional baseload per launch, kg	Additional baseload per year, kg	Total annual requirement, metric tons	
					KSC (40 flights/year)	VAFB (20 flights/year)
Hydrogen (ℓ)	Fuel for Orbiter main engines	102 500	70 760	162 400	7 090	3 630
Oxygen (ℓ) -- propellant grade	Oxidizer for Orbiter main engines	609 600	454 200	3 629 000	46 160	24 900
Oxygen (ℓ) -- high purity	Fuel cell reactant and life support	1 360	5 440	0	272	136
Helium (g)	Pressurant; purge and leak check	91	5 560	32 400	258	145
Nitrogen (g)	Pressurant; purge and leak check	96	212 400	27 220 000	35 720	31 470
Nitrogen (ℓ)	Refrigerant and life support	0	90 700	1 814 000	5 440	3 630
MMH (ℓ)	Fuel for OMS and RCS	5 370	0	3 630	218	111
Nitrogen tetroxide (ℓ)	Oxidizer for OMS and RCS	7 870	0	5 440	320	163
Hydrazine (ℓ)	Fuel for auxiliary power system	675	0	0	27	13.5
Mixed oxides of nitrogen	Enrichment of nitric oxide content in nitrogen tetroxide	900	0	0	36	18
Freon-113 -- ClF_2C-CCl_2F (ℓ)	System flush and cleaning agent	[illegible]	10 425	500 000	1317	908
Isopropyl alcohol	System flush and cleaning agent	0	18 000	5 900	726	366
Ammonia (ℓ)	Orbiter coolant loop	39	0	0	1.6	.8
FC-40 -- completely fluorinated hydrocarbon (ℓ)	Orbiter fuel cell coolant	[a]45	0	270	.3	.15
Freon-21 -- Cl_2CH (ℓ)	Orbiter radiator coolant	[a]4.5	[a]635	2 630	[illegible]	1.3
Demineralized water (ℓ)	Sound suppression, flush SRB's, and cleaning	0	603 000	[illegible] 600 000	[illegible]	19 600
Coolant water (ℓ)	System coolant	[a]124	0	680	.7	.35
Crew potable water (ℓ)	Crew's drinking water	91	0	0	[illegible]	1.8
Hydrochloric Acid (ℓ) 31.5% solution	Regenerant for producing demineralized water	0	[illegible] 360	33 900	88	61
Sodium hydroxide (ℓ) 50% solution	Neutralizing agent and regenerant, as above	0	3 230	39 500	169	104
Diesel fuel (ℓ)	Fuel for rechargers	0	0	39 000	39	20
Hydraulic fluid (ℓ)	Orbiter hydraulic systems	980	0	2 300	2.3	1.2
Bromotrifluoromethane (ℓ)	Fire-extinguishing agent	[a]5.4	0	5 440	5.4	[illegible]

[a]This is not a per-launch consumable requirement but rather a function of scheduled maintenance; see yearly baseload value.

TABLE 8-2.-- SPACE SHUTTLE FLIGHT PHASE SOLID PROPELLANT REQUIREMENTS

Solid propellant ingredient	Purpose	On-board quantity, kg	Manufacturing waste per launch, kg	Total per flight, kg	Total annual requirement, metric tons (60 per year)
SRM propellant (2 motors per launch):					
Ammonium perchlorate	Oxidizer	701 514	5011	706 525	42 390
Aluminum powder	Fuel	161 268	1152	162 420	9 745
PBAN binder	Binder/fuel	141 109	1008	142 117	8 527
Iron oxide	Combustion accelerator	4 032	29	4 061	244
Total		1 007 923	7200	1 015 123	60 906
SRM igniter propellant (2 motors per launch):					
Ammonium perchlorate	Oxidizer	136	1.5	137.5	8.3
Aluminum powder	Fuel	4	--	4.0	.2
PBAN binder	Binder/fuel	32	.4	32.4	1.9
Iron oxide	Combustion accelerator	5	.1	5.1	.3
Total		177	2.0	179.0	10.7
SRM separation motors (16 motors per launch):					
Ammonium perchlorate	Oxidizer	397	4.2	401.2	24.1
Aluminum powder	Fuel	9	.1	9.1	.5
HTPB binder	Binder/fuel	66	.7	66.7	4.0
Total		472	5.0	477.0	28.6
Total solid propellant requirement:					
Ammonium perchlorate	Oxidizer	702 047	5017	707 064	42 424
Aluminum powder	Fuel	161 281	1152	162 433	9 746
PBAN binder	Binder/fuel	141 141	1008	142 149	8 529
HTPB binder	Binder/fuel	66	0.7	67	4
Iron oxide	Combustion accelerator	4 037	29.1	4 066	244
Total		1 008 572	7206.8	1 015 779	60 947

TABLE 8-3. -- COMPARISON OF MAJOR MATERIAL REQUIREMENTS FOR THE SPACE SHUTTLE PROGRAM

Major consumable material	Current Space Shuttle supplier[a]	Annual U.S. Production: Amount, thousand metric tons	Annual U.S. Production: Year	Annual U.S. Production: Reference	Peak annual requirement, thousand metric tons	Space Shuttle requirement divided by total U.S. production
Space Shuttle propellants and fluids						
PBAN binder	American Synthetic	[b]0.4	1975	(c)	8.5	21.25
Ammonium perchlorate	Kerr-McGee/Pacific Engineering	[d]7.0	1975	8-2	42.4	6.06
MMH	Olin Chemical	1.6	1977	(e)	.3	.19
Aluminum powder	ALCOA/ALCAN	80.0	1974	8-3	9.7	.12
Freon-113	Dupont/Allied Chemical	[f]34.0	1976	(g)	2.2	.06
Nitrogen tetroxide	Vicksburg/Valley Nitrogen	10.7	1977	(e)	.5	.05
Hydrogen	Air Products and Chemicals	510.0	1968	8-4	10.7	.02
Helium	U.S. Bureau of Mines	24.5	1968	8-4	.4	.016
Nitrogen	Many	5 188	1970	8-4	76.3	.015
Oxygen	Many	72 175	1970	8-4	71.5	.001
Isopropyl alcohol	Many	913	1969	8-4	1.1	.001
Space Shuttle hardware						
Aluminum	Many	4 450	1974	8-3	1.8	.0004
Copper	Many	132 000	1974	8-3	.4	3×10^{-6}
Steel	Many	1 390	1974	8-3	.008	6×10^{-6}

[a] Current suppliers may change as a result of competitive procurement action of the future.

[b] Current PBAN annual capacity is estimated at 2.7 thousand metric tons (estimate provided by Art Goreham).

[c] This figure was provided by Art Goreham of American Synthetic Rubber Company (personal communication on Aug. 18, 1975).

[d] Current ammonium perchlorate annual capacity is estimated at 21 thousand metric tons (ref. 8-3).

[e] This figure was provided by Charles Lowe of Kelly Air Force Base (personal communication on Feb. 15, 1977).

[f] This is only an estimate (provided by R. Davis).

[g] This figure was provided by R. Davis of Dupont Chemical Corporation (personal communication on Feb. 22, 1977).

binder and ammonium perchlorate oxidizer for the SRB's propellant. Uses of these materials for purposes other than for propellants used in SRM's are trivial.

Table 8-3 indicates that approximately 42 000 metric tons (46 700 tons) of ammonium perchlorate and 8500 metric tons (9400 tons) of PBAN binder would be required to support 60 Space Shuttle launches per year. As indicated, the only ammonium perchlorate produced on a large scale is manufactured in Henderson, Nevada, by two companies -- Kerr McGee and Pacific Engineering. If their current total capacity would be dedicated to SRM propellant, about 30 Space Shuttle flights per year could be satisfied. The 60 Space Shuttle flights per year would require the expansion of ammonium perchlorate production facilities. American Synthetic of Louisville, Kentucky, the producer of PBAN, would have to triple its current production capacity to be able to supply the binder ingredients needed for 60 Space Shuttle flights per year. Other major materials shown in table 8-3 are well within the U.S. current production capacity. Other materials requirements not shown in table 8-3 (see sections 8.1.1.1 to 8.1.1.4) are believed to be significantly below U.S. production capacity.

8.1.2 Energy Requirements

The energy requirements for the Space Shuttle Program are separated into two classes: energy for the development phase (1970-1979) and energy for the flight phase (1979-1991). Sections 8.1.2.1 and 8.1.2.2 discuss quantitative energy estimates for the two phases of the program. Section 8.1.2.3 compares these energy estimates to other activities and discusses potential energy impacts.

8.1.2.1 Energy Requirements for the Development Phase

The energy requirements for the 10-year, $6.9-billion Space Shuttle development phase have been estimated by equating dollars to energy. Dollar/energy conversion factors have been calculated by dividing the total annual energy consumption (including consideration of electric power plant efficiency) by the total net sales for various aerospace companies. Typically, values ranging from 4000 to 9000 kJ (3792 to 8532 Btu) per 1971 dollar are characteristic of companies located in southern California. Companies in northern climates exhibit somewhat higher values. NASA centers have exhibited factors both above and below 10 000 kJ (9480 Btu) per 1971 dollar. Therefore, a 10 000-kJ per-dollar figure has been selected as an overall dollar/energy conversion factor to estimate the energy requirements for the Space Shuttle's development phase.

Figure 8-1 shows the estimated annual energy requirements as a function of year. Estimates are based upon 10 000 kJ per 1971 dollar and the projected annual 1971-dollar NASA obligation. The peak energy requirement to support the development phase of the program occurs in 1976, at about 10×10^{12} kJ. The average over the 1970-1980 time period is 4.7×10^{12} kJ. This estimate considers all possible forms of energy, including the fossil fuel used to produce consumed electricity.

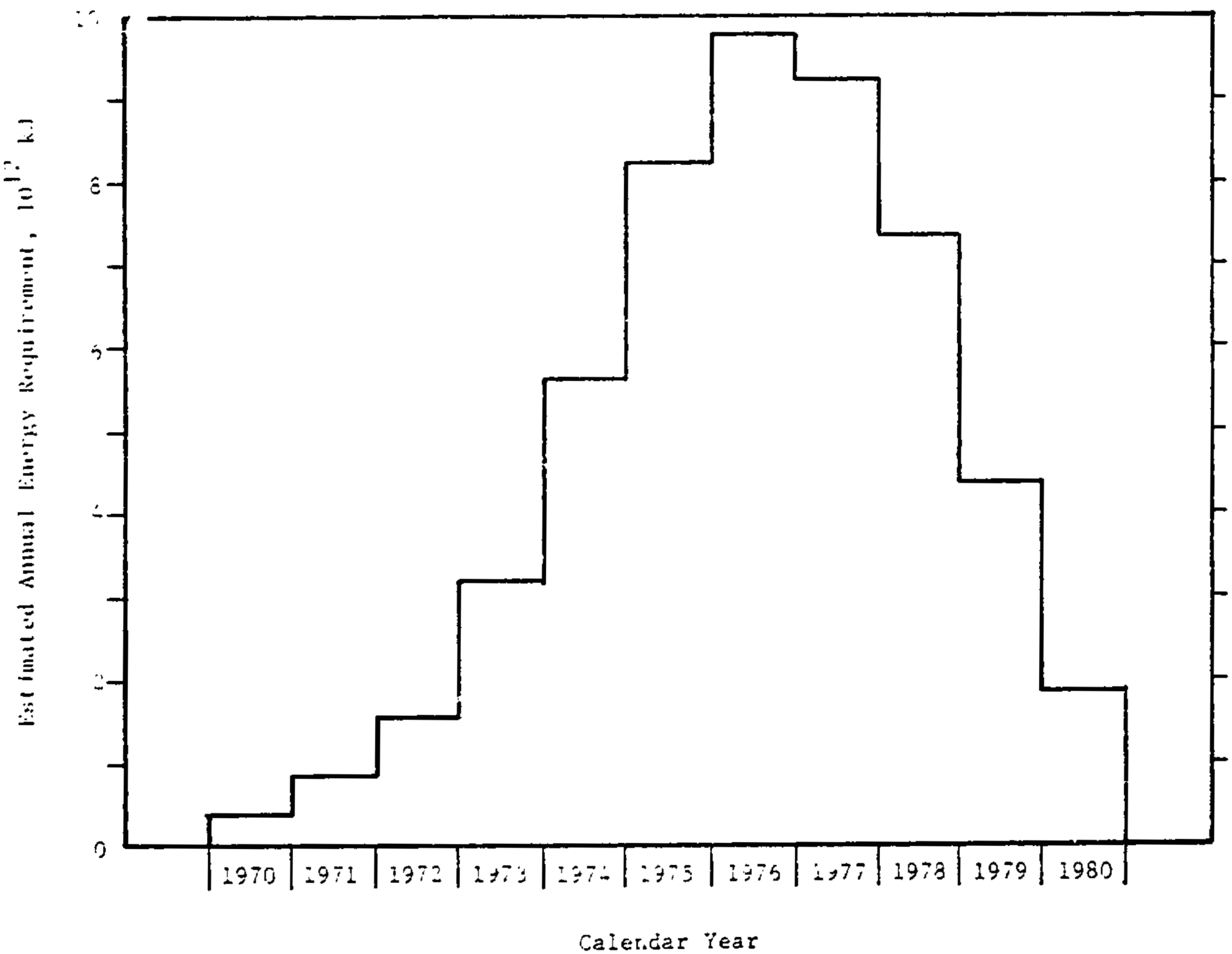

Figure 8-1.-- Estimated annual energy requirements for Space Shuttle development phase.

8.1.2.2 Energy Requirements for Flight Operations Phase

The energy required for the Space Shuttle's flight operations can be divided into two categories -- one category which includes the energy required to produce major raw materials and another which includes energy required during operational support of the Space Shuttle system. Energy for operational support includes energy required for (1) manufacture and/or refurbishment of Space Shuttle hardware at NASA contractor locations and (2) all NASA center and DOD support activities.

Table 8-4 lists the estimated annual fluids and raw materials required for 60 Space Shuttle flights per year. Space Shuttle propellants alone constitute more than 95 percent of the total annual fluids and materials' energy requirement of 15.7 x 10^{12} kJ (15 x 10^{12} Btu). The processing of liquid hydrogen, ammonium perchlorate, and aluminum powder represents more than 75 percent of the total annual requirement.

Table 8-5 lists the estimated annual operational support energy requirements for the 60 Space Shuttle flights per year. The energy estimates are based on 1971 dollar estimates for costs anticipated during Space Shuttle operations and dollar/energy conversion factors for various types of activities. The total estimated requirement to support Space Shuttle operations at the rate of 60 flights per year is 8.8 x 10^{12} kJ (8.4 x 10^{12} Btu). The activities that involve the processing of the SRB and construction of new External Tanks involve more than 50 percent of the total energy for a given year. Thus, the total annual energy required to support the flight phase of the Space Shuttle Program at 60 launches per year is approximately 24 x 10^{12} kJ (23 x 10^{12} Btu) per year.

8.1.2.3 Energy Consumption Impacts

The peak annual energy required to perform the Space Shuttle's development and flight operations are 9.7 and 24.4 x 10^{12} kJ, respectively. Analysis (ref. 8-5) indicates that approximately 60 percent of the total flight requirement is energy consumed in the generation of electric power and that 40 percent is directly consumed as fossil fuel. Fossil fuels to be used during Space Shuttle Program activities include natural gas, coal, oil, diesel gas, aviation gas, and gasoline. The required electricity will be generated at plants generating electricity from hydrostatic, nuclear, oil, coal, and natural gas power sources. Table 8-6 summarizes the Space Shuttle energy requirements and compares them to annual energy requirements of two other activities. For example, the total amount of energy required to support Space Shuttle launches is about 25 percent of the fuel consumed by general aviation in 1971 and about 1.7 percent of the fuel consumed by commercial airplanes in 1971. The peak Space Shuttle requirement is expected to be less than 0.03 percent of the total U.S. energy requirement during the 1980's. Based on economic and energy comparisons, the Space Shuttle Program is not considered to be an energy-intensive activity. Hence, the Space Shuttle Program is not expected to impose significant energy impacts to the nation as a whole. Continued effort will be made, however, to reduce energy consumption wherever possible.

TABLE 8-4.-- ESTIMATED ANNUAL ENERGY REQUIREMENTS OF FLUIDS AND MATERIALS FOR 60 SPACE SHUTTLE FLIGHTS PER YEAR

Fluids and materials	Total mass,[a] kg	Conversion factor,[a] kJ/kg	Total energy, 10^{12} kJ
Major liquid propellants or fluids:			
Hydrogen (ℓ)	10 720 000	460 000	4.93
Oxygen (ℓ)	71 468 000	9 715	.69
Helium (g)	403 000	536 000	.22
Nitrogen (g+ℓ)	67 190 000	7 170	.55
MMH (ℓ)	329 000	363 000	.12
Hydrazine (ℓ)	40 500	285 000	.01
Nitrogen tetroxide (ℓ)	483 000	30 300	.01
Freon-113 (ℓ)	2 225 000	95 000	.21
Isopropyl alcohol (ℓ).	1 092 000	50 000	.05
Subtotal			6.79
Solid propellants (SRB and separation motor):			
Aluminum powder.	9 746 000	323 000	3.15
Ammonium perchlorate	42 424 000	97 000	4.14
PBAN binder	8 529 000	84 000	.72
Other.	248 000	16 000	.01
Propellant process energy. . . .	60 947 000	3 000	.18
Subtotal			8.20
External tank materials:			
Aluminum	1 722 000	323 000	.56
Stainless steel.	54 420	92 000	.01
Copper	7 380	148 000	-
Other.	155 000	50 000	.01
Subtotal			.58
SRB materials (20 uses):			
Aluminum	69 960	323 000	.02
Steel.	315 960	58 000	.02
Stainless steel.	61 240	92 000	.06
Insulation	777 720	76 000	.02
Other.	663 000	50 000	.03
Subtotal			.14
Orbiter materials (100 uses):			
Aluminum	21 780	323 000	.01
Stainless steel	9 900	92 000	
Copper	940	148 000	
Titanium	420	406 300	
Other	11 940	50 000	
Subtotal			<.01
Total annual fluids and materials energy			15.72×10^{12} kJ

[a]Data are based on references 8-1 and 8-6.

TABLE 8-5.-- ESTIMATED ANNUAL OPERATIONAL SUPPORT ENERGY REQUIREMENTS FOR 60 SPACE SHUTTLE FLIGHTS PER YEAR

Operational support	Total cost, 1971 $M[a]	Conversion factor, kJ/1971 $[a]	Total energy, 10^{12} kJ
Prorated Orbiter construction (includes main engine but excludes materials)	160.2	6 600	1.06
SRB (excludes propellants)	156.0	20 400	3.18
External Tank construction (excludes materials)	171.6	8 600	1.48
Spare parts manufacture	48.0	7 800	.37
NASA/KSC operational support	82.2	8 600	.71
NASA/JSC operational support	55.2	15 300	.84
Other indirect launch support (other centers and contractors)	93.0	12 000	1.12
Total annual operational support energy			8.76

[a]Data are based on reference 8-5.

TABLE 8-6.-- ENERGY REQUIREMENTS FOR THE SPACE SHUTTLE PROGRAM AND COMPARISON EXAMPLES

Category	Annual energy consumption, 10×10^{12} kJ
Space Shuttle development phase:	
Peak estimated requirement (1976)	9.7
Average estimated requirements (1971-1980).	4.7
Space Shuttle flight phase (60 flights/yr):	
Liquid propellants and fluids	6.8
Solid propellants	8.2
External Tank (less propellants).	2.1
SRB (less propellants).	3.3
Orbiter (less propellants)	1.1
Other support activities (NASA, DOD, contractor). .	3.0
Total	24.4
Comparison examples (ref. 8-11):	
Fuel consumed by general aviation in 1971	100.0
Fuel consumed by commercial airplanes in 1971 . . .	1500.0

There may be some local energy impacts caused by the Space Shuttle Program, since increases in processing of the raw materials will be required (see section 8.1.1). The more significant local energy impacts are given in table 8-7.

Other localized changes in electric or fossil fuel consumptions are not expected, as specific other Space Shuttle Program activity (NASA, DOD, and contractor) will be replacing existing activity related to expendable launch vehicle manufacture and other types of manufacturing activity.

8.1.3 Changes in Biological Resources

Small areas of wildlife habitat will be converted to buildings, runways, and other facilities associated with the Space Shuttle Program. Component manufacture and test areas are predominantly located in industrial settings where wildlife use is already minimal. Launch and support facilities at KSC and VAFB are located within wildlife preserves/refuges which are managed for wildlife and utilized for space launch support functions. Alterations at rocket test facilities (Thiokol/Wasatch, NSTL, and Santa Susana) will not result in loss of wildlife support capabilities at these facilities or in their buffer areas.

8.2 Cultural Resources

Changes to cultural resources, such as employment, land-use, recreational and historical resources, are addressed below. No significant adverse changes are expected. Section 4.7 contains a more detailed discussion of cultural resource impacts.

8.2.1 Employment

The work of NASA, the USAF, and contractor employees on the Space Shuttle will represent a commitment of manpower. Other than construction activities, the Space Shuttle Program will employ skilled, highly skilled, and professional workers. In view of the current and long-term demand for these skill levels and the benefits to society that will result from the Space Shuttle Program, this commitment of manpower resources is considered a benefit of the program.

Construction programs have been minimized through the use of existing facilities. Construction workers will be required in some numbers at both KSC and VAFB for modification of facilities and construction of others. The demand will not be great and is well within the community support capacity developed during earlier programs. Ideally, much of the labor force can be drawn from local or near-by labor markets since planned activities are not of sufficient magnitude or duration to attract workers from remote labor markets.

TABLE 8-7.-- LOCAL ENERGY IMPACTS CAUSED BY THE SPACE SHUTTLE PROGRAM

Geographical area[a]	Activity	Comment
Henderson, Nev.	Manufacture of ammonium perchlorate	Both ammonium perchlorate manufacturers rely on hydro- and coal-generated electric power. Energy requirements may increase by a factor of ∿20 to accommodate anticipated production rates.
Louisville, Ken.	Manufacture of PBAN	Coal-generated steam process heat required in the manufacturing of PBAN would be increased by a factor of ∿6 over current usage.
New Orleans, La.	Manufacture of liquid hydrogen	Air Products and Chemicals, Inc., will bring a new plant on line to generate liquid hydrogen. Local natural gas and electric power will be required.
Rockdale, Tex.	Manufacture of aluminum powder	Aluminum powder will be generated in Canada and in the United States. Canadian aluminum (ALCAN) will be produced using mostly hydroelectric power. Texas-based production (ALCOA) will require an increase in natural gas consumption.
Promontory, Utah	SRM processing	Modest increases in electric and fossil fuel consumption (+25%) are expected over current usage.
Bay St. Louis, Miss.	Manufacture of the external tank	Increases in electric power requirements for the manufacture of the external tank are anticipated.

[a]These areas could change if different contractors are acquired as a result of procurement activities.

8.2.2 Land-Use, Recreational, and Historical Resources

No significant irretrievable commitment of land-use, recreational, or historical resources is expected to result from the Space Shuttle Program. Land-use restrictions and historical preservation agreements and restrictions will be maintained by NASA, the USAF, and their contractors for the duration of the Space Shuttle Program. Recreational facilities, operated under current or future agreements, will not be directly affected by the Space Shuttle Program. The temporary restrictions on public access to such facilities prior to launches do not irretrievably commit the resource.

9. OTHER CONSIDERATIONS THAT OFFSET POTENTIAL ENVIRONMENTAL EFFECTS

Current plans call for the Space Shuttle to replace the current fleet of expendable launch vehicles in the early 1980's. In the past, the space program, mostly served by expendable launch vehicles, has helped to enhance the quality of life by permitting improved monitoring and managing of resources and global communications and in advances in science and technology. In the future, the Space Shuttle vehicle will contribute to the expansion in the use of space for these and other purposes by providing low-cost access to space. Users of the Space Shuttle will include communication networks, research foundations, universities, observatories, federal departments and agencies, state agencies, county and city planners, public utilities, farm cooperatives, the medical profession, the fishing industry, the manufacturing industry, the transportation industry, water conservation planners, and foreign countries.

Section 7 describes long-term environmental benefits which are expected to offset the potential adverse environmental effects of the Space Shuttle Program (see section 6). The following paragraphs describe other benefits that will be derived from the Space Shuttle Program.

The space program has benefited many segments of the Nation favorably: science, commerce, industry, education, agriculture, aviation, communications, ecology, medicine, and national security. Advances in technical fields have been stimulated at an unprecedented pace and have been a significant factor in helping the United States to maintain a position of technological leadership.

Continued space activities can yield significant long-term improvements to life on Earth. To achieve these improvements, it is first necessary to operate more economically in space so that its full utilization will be possible within the larger context of other national goals and programs. The Space Shuttle will reduce the cost of space transportation by providing a reusable system with a flexible launch rate capability and a short turnaround time. In addition to the transportation savings, very significant economies will be realized in reduced payload costs because of relaxed weight and volume constraints; capability to revisit and return payloads for repair and reuse; and safe, intact mission abort and subsequent return of payloads. In particular, the following programs will be far more productive through utilization of the Space Shuttle.

- *Communications:* Satellite communications systems have already made great contributions to improved global and domestic communications. The use of the Space Shuttle will allow the use of more effective systems in orbit at lower cost. New systems will permit introduction of a range of services that will provide new benefits, including search and rescue of downed aircraft, direct broadcast to home-type receivers, and personal communications devices (such as wrist radios) operating through satellite relay. Advanced traffic control and navigation satellites, launched by the Shuttle, should greatly aid aviation and ocean shipping.

• Traffic and navigation: Advanced traffic and navigation satellites to be launched by the Space Shuttle in the 1980's will increase safety and accuracy of ship and air travel throughout the world. Air traffic control will be more accurate because air traffic controllers will be able to pinpoint both the position and speed of aircraft. This should minimize mid-air collisions and loss of life, thus making air travel even safer than it is today. In the same way, the possibility of collisions between ships on the high seas will be reduced. This may be of particular significance to fossil fuel transport on the oceans.

• Space science and exploration: The ability to carry out scientific observations in astronomy, solar physics, and space physics will be enhanced by the ability of the Space Shuttle to place in orbit such major observational instruments as space telescopes and return them to Earth for refurbishment when their initial purposes have been served or when they have malfunctioned. Scientific research will be performed in the completely equipped, manned scientific research laboratory (Spacelab) being built by the ESA for transport to orbit by the Space Shuttle. The Space Shuttle will also be used to carry planetary and interplanetary exploration spacecraft and their escape stages to orbit for launch into deep space.

• Life science research: Life science research in space using Spacelab and other laboratories placed into orbit by the Space Shuttle will increase man's knowledge of life processes. Considerable benefits may be derived in the use of the zero gravity environment during certain convalescences and for the manufacture of special drugs.

• New products from space: The Space Shuttle will provide a means to perform, in space, manufacturing or space processing activities. The conditions of weightlessness and vacuum make it possible to process materials that would otherwise be impossible or prohibitively difficult to process on Earth. Melting and mixing without the contaminating effects of containers, the suppression of convection currents and buoyancy in liquids and molten material, the control of voids, and the ability to use electrostatic and magnetic forces otherwise masked by gravity, open the way to a new knowledge of material properties and processes. This may ultimately lead to the development of valuable new products for use on Earth. Selected manufacturing or processing of certain hazardous materials which is, or would be, performed on Earth could be moved to space, perhaps thus minimizing possible adverse environmental effects to the Earth.

• Space power and relay satellites: During the 1980's, the Space Shuttle may carry to orbit experimental space power and relay systems. Although only in the early stage of study, a number of possibilities exist for the collection of solar energy in space and its transmission to Earth for use in alleviating the anticipated shortages of energy. The Space Shuttle will make possible the research to help determine the technological, economical, and environmental feasibility of such concepts.

• International relations: The Space Shuttle Program is expected to play a constructive role in international relations. A number of nations are currently involved in producing components of the STS. The ESA is committed to spending hundreds of millions of dollars in the development

of the Spacelab. Contributing nations include West Germany, Belgium, Denmark, Spain, France, Italy, the Netherlands, the United Kingdom, and Switzerland. Canada is developing manipulator arms for the Orbiter, which will be used to manipulate payloads in and out of the Space Shuttle payload bay. It is anticipated that Space Shuttle users will include at least the many nations just mentioned; the ability of the Space Shuttle to provide launch services at lower cost should markedly increase foreign participation in space programs and hence increase international cooperation.

- National defense: The U.S. Department of Defense is currently planning to use the Space Shuttle vehicle to launch payloads vital to the security of the United States. Thus, the Space Shuttle Program will become a major contributor to national defense posture.

- Economics: To a large degree, the United States relies on the government-industry aerospace team to maintain favorable trade balances. Expanded exports of high-technology products help offset the traditional negative balances in minerals, raw materials, fuels, and low-technology manufactured goods. In this regard, the Space Shuttle Program will contribute favorably to the U.S. trade posture in two ways: It will help set the pace of technology because of its highly stimulative effects on those technology-intensive industries that are depended upon for a high dollar volume of exports; and it will contribute directly by launching and servicing the satellites of other nations. The funds spent upon this program and the jobs created contribute importantly to the economic health of the nation. Each $100 million of NASA expenditures is estimated to establish about 4000 direct jobs among NASA contractors and their suppliers. In addition, about 6000 additional jobs are created as the direct employees spend the income earned from the NASA activity. The spending and respending of these funds lead to a multiplier of about 2 in the gross national product; i.e., each dollar of NASA spending increases the real gross national product by about $2.00. Because NASA spending tends to be in industries with higher than average productivity, these expenditures tend to increase the national average productivity and thus to be counterinflationary.

Of considerably more significance are the long-term contributions of NASA R&D to the economy. Economists have long known that technological advance is a major source of higher productivity and economic growth and that R&D is an important contributor to the advancement of technology. Evidence that highly technological efforts such as the Space Shuttle and other space program activities have a beneficial effect on the economy much greater than average is now available (refs. 9-1 and 9-2). Reference 9-2, in particular, analyzed the macroeconomic impact of NASA spending and estimated an annual rate of return to NASA spending of about 40 percent. On the basis of simulations conducted with a complex national macroeconometric model, NASA spending was predicted to induce, through the resulting technological advance, significant beneficial economic effects, including a lower inflation rate, increased job opportunities, lower unemployment and increased real gross national product.

These effects, particularly the unique combination of increased real gross national product and a lower inflation rate, stem from the growth in general productivity that results from high-technology R&D. Growth in productivity means that less labor (and/or capital) is needed per unit of output. This results in lower unit labor costs and hence lower prices. A lower rate of inflation leads in turn to a more rapid rise in real disposable income, which provides consumers with the additional purchasing power to buy the additional goods and services made possible by the expansion of the economy.

10. COMMENTS RECEIVED AND NASA RESPONSES

Comments on the draft environmental impact statement for the Space Shuttle Program (released August 5, 1977) were requested from Federal agencies, state clearing houses, and interest groups (see item 6 of the Summary). Comments were received in the form of letters from 10 Federal agencies, 18 states, and 1 interest group.

10.1 COMMENTS RECEIVED REQUIRING NASA RESPONSE

Copies of all letters received on the draft environmental impact statement that elicited a response from NASA are included in this section. The following agencies sent letters:

C-3

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C.

RECEIVED

OCT 17 12 23 PM '77

14 OCT 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
NASA
Washington, DC 20546

Dear Dr. Malkin

The draft Environmental Impact Statement (EIS) for the Space Shuttle Program dated July 1977 has been reviewed by the Air Force and the following comments are provided for your consideration:

1. Page 34, Table 2-2: This table does not agree with the mission model shown in the draft EIS for the Space Shuttle Program at Vandenberg AFB. Cite specific mission model used for this table.

2. Page 61, Sect 4.2.1.1.1, Line 12: Climatological data for 45 randomly selected days in 1969 were used as inputs and provided data representative of the entire year. The document indicates those days were Wednesdays. The dates given for the illustrative data in this paragraph indicates that the days were selected randomly without regard to day of the week.

3. Page 67, Table 4-5: Table 4-5 has column titled "Ceiling Limits". None of the stated references contain any of the listed "Ceiling Limits". Some of the references list emergency exposure limits (EELS) that match these "ceiling limits" (e.g., MMH and Hydrazine); however, EELS were established for military and space personnel.

4. Page 109, Para 2: Indicate impact assessment of sonic boom inpingement on the channel islands.

5. Page 109, Sect 4.5.3: What is the areal extent of SRB sonic boom inpingement at surface relative to the 280 to 370 KM downrange distances indicated? The Port Hueneme-Oxnard-Los Angeles area could be impacted.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

6. Page 113, Sect 4.5.5.1, Para 1: Clarify whether overpressures inside cars cited result from doors being in a closed position or when doors with windows up are abruptly closed (slammed).

7. Page 114, Para 2: The statement by International Civil Aviation Organization (ICAO) that probability of direct injury to persons exposed to sonic boom is essentially zero seems to conflict with the Committee on Hearing, Bio-acoustics and Biomechanics (CHBB) limit on previous page. The focus zone during ascent certainly exceeds the CHBB limit.

8. Page 116, Para 2: The startle effects alone may expose eggs to predation by western gulls. Does NASA plan to conduct further studies on the effects of sonic booms on wildlife?

9. Page 133, Table 4-11: Previous NASA information indicated as much as 170 lbs of propellant could remain in the Solid Rocket Boosters (SRB) at ocean impact. Table 4-11 indicates 0. Please verify.

Thank you for allowing our agency the opportunity to review this draft EIS. We would appreciate receiving two (2) copies of the final EIS when released.

Sincerely

Hisao Yamada

HISAO YAMADA, Colonel, USAF
Chief, Environmental Planning Division
Directorate of Engineering & Services

U.S. Department of the Air Force, Environmental Planning Division, Washington, D.C.

Comment: Page 34, Table 2-2, does not agree with the mission model shown in the final environmental impact statement for the Space Shuttle Program at VAFB. Cite the specific mission model used for this table.

Response: The mission model given in table 2-2 of this statement correctly identifies the flights per calendar year from VAFB. The reference is the Space Shuttle Program Status Report, September 30, 1977. The final environmental impact statement for the Space Shuttle Program at VAFB is in accord with the same reference on a flights-per-fiscal-year basis. No change to the text has been made as a result of this comment.

Comment: Page 61, section 4.2.1.1.1, line 12: Climatological data for 45 randomly selected days in 1969 were used as inputs and provided data representative of the entire year. The document indicates that those days were Wednesdays. The dates given for the illustrative data in this paragraph indicate that the days were selected randomly without regard to the day of the week.

Response: The intent of the study performed by NASA quoted in this statement was to determine the envelope of hydrogen chloride concentrations for a full year of Space Shuttle operations from KSC. The meteorological data most appropriate for this study were those obtained during twice daily soundings from the Eastern Test Range in 1969. Wherever possible, the computed hydrogen chloride concentrations related to a morning launch on Wednesday of each week of that year, except when there was no sounding on a particular Wednesday and another day was substituted and in certain instances when a particular meteorological regime existed during an evening sounding. It is fortuitous that the envelope shown in figure 4-2 and the statement cited in section 4.2.1.1.1 refer to two dates that are not Wednesdays. Furthermore, the March 18 result was taken from an evening launch (table 4-3). NASA is currently investigating assumed Space Shuttle launches during 1965 when there were four soundings each day from the Eastern Test Range. Because the launches will not be restricted to a particular day or time, the resulting envelope of hydrogen chloride concentrations, coupled with the 1969 results, will represent a random selection of possible meteorological regimes for actual Space Shuttle operations. To clarify this point, the last four sentences in the second paragraph of section 4.2.1.1.1 have been rewritten as follows:

> For the calculation of the curves shown in this figure, climatological data were selected for 45 days spaced approximately a week apart during 1969. In this way, data representing the entire year are included. Whenever possible, data from the Wednesday morning soundings were used. Figure 4-2 shows only the envelope of the 45 cases calculated. Details of the case which gave the highest hydrogen chloride concentrations are provided in table 4-3 (ref. 4-2).

U.S. Department of the Air Force, Environmental Planning Division, Washington, D.C. (continued)

Comment: Page 67, Table 4-5, has a column titled "Ceiling Limits." None of the stated references contain any of the listed "Ceiling Limits." Some of the references list emergency exposure limits (EELS) that match these "ceiling limits" (e.g., MMH and hydrazine); however, EELS were established for military and space personnel.

Response: It is correct that the stated references do not contain any of the listed ceiling limits. The values and terminology resulted from NASA interpretation of a letter from the Director, Advisory Center on Toxicology, National Research Council (ref. 10-2). Explanatory paragraphs have been added to the text in section 4.2.1.1.1(a) as follows:

> The STPL's and PEL's are time-weighted averages. Excursions above the limit must be counterbalanced by an equal time below the limit. They are further governed by maximum excursion limits. In the case of hydrogen chloride, the Committee on Toxicology recommended on December 6, 1972 (ref. 10-2), pending the generation and evaluation of new data, that an excursion by a factor of 2 above the guide values may be tolerated for no more than 5 min.
>
> This means that for no more than 5 min, exposure to hydrogen chloride may be as high as 8 ppm; this must be counterbalanced, in the case of the 10-min limit, by cessation of exposure to hydrogen chloride. Under these limits, there can be no predictable exposure to more than 8 ppm, no matter how short the time. This maximum excursion has been called the ceiling limit. The PEL's are also governed by the concept of time-weighted averages, with an excursion factor of 2. In case of an accident, an exposure for 5 min to 14 ppm would be balanced by cessation of exposure. No accidental, unpredictable exposure to more than 14 ppm is recommended, no matter how short the time. The same ceiling limit concept has been applied to the PEL's.
>
> Although the Committee on Toxicology referred only to the case of hydrogen chloride in its discussion, the same concept has been applied to all the toxicants listed in table 4-5 in the absence of any other guidelines.

Comment: Page 109, paragraph 2: Indicate impact assessment of sonic boom impingement on the Channel Islands.

Response: The impact assessment requested is mentioned in the second paragraph of section 4.5.5.2 of this statement. The text has been modified to include a cross reference in the last paragraph of section 4.5.2.

Comment: Page 109, section 4.5.3: What is the areal extent of SRB sonic boom impingement at surface relative to the 280 to 370 km downrange distances indicated? The Port Hueneme-Oxnard-Los Angeles area could be impacted.

Response: The SRB sonic boom is estimated to cover an area of about 150 km (93 miles) in diameter. The effect will occur between north latitudes of 31.5 and 32.5 degrees. This is far south of, and away from (even on the 160-degree launch azimuth), the California coast. The sonic boom will not impact the mainland. No change to the text has been made as a result of this comment.

Comment: Page 113, section 4.5.5.1, paragraph 1: Clarify whether overpressures inside cars cited result from doors being in a closed position or when doors with windows up are abruptly closed (slammed).

Response: The overpressures given in section 4.5.5.1 are generated when the car doors are slammed shut with windows up. A phrase has been added to the appropriate sentence in section 4.5.5.1, so that the sentence reads: "For example, the overpressures inside a car when the door is slammed (windows raised) are up to 200 N/m^2 (4 psf) for standard sedans and station wagons and up to 425 N/m^2 (8.5 psf) for compact cars."

Comment: Page 114, paragraph 2: The statement by the ICAO that probability of direct injury to persons exposed to sonic boom is essentially zero seems to conflict with the CHBB limit on the previous page. The focus zone during ascent certainly exceeds the CHBB limit.

Response: The ICAO statement was a general one referring to the effect of booms produced by normal flight operations of supersonic aircraft. The overpressures for such flights do not exceed the CHBB limit. The statement also applies to the anticipated results when the sonic boom of the Orbiter at entry is experienced by populated areas. The focused boom during launch when the vehicle pitches over produces an exceptionally high sound pressure over a very narrow region. Inside this zone, the CHBB limit is exceeded; however, this occurs only over the ocean or in uninhabited areas.

To clarify this point, the fourth paragraph in section 4.5.5.1 has been modified to read as follows: "In reviewing the effects of sonic booms produced by supersonic aircraft during normal flight operations, the ICAO found that. . . ."

Comment: Page 116, paragraph 2: The startle effects alone may expose eggs to predation by western gulls. Does NASA plan to conduct further studies on the effects of sonic booms on wildlife?

U.S. Department of the Air Force, Environmental Planning Division, Washington, D.C. (continued)

Response: NASA has no plans to sponsor or conduct studies on the effects of sonic booms on wildlife. However, the USAF plans to sponsor various studies on the effect of sonic booms on brown pelicans in the Channel Islands. No change to the text has been made as a result of this comment.

Comment: Page 133, table 4-11. Previous NASA information indicated that as much as 170 lb of propellant could remain in the SRB at ocean impact. Table 4-11 indicates zero. Please verify.

Response: The figure derived from the SRB Mass Property Status Report, No. 47 (Sept. 15, 1977, p. 30) gives a residual propellant amount at splashdown of about 130 lb. This figure is based on estimates by Thiokol from past experience with solid rocket boosters. It is expected that a firmer figure will be available after completion of the SRB qualification test. The 177-lb figure is an upper limit, and table 4-11 has been modified accordingly.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

OFFICE OF THE SECRETARY

WASHINGTON, D.C. 20201

ADA-1

A, ADA, AR, AS, B, G, M

A 34837

10-11-77

DONE

OCT 7 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Sir:

Thank you for the opportunity to review the draft Environmental Impact Statement on the Space Shuttle Program.

Various environmental impacts could be reduced by taking them into consideration during the planning of launch dates. As stated on page 74, "Control of acidic rain in the general region of the launchsite can be achieved by the proper choice of meterological conditions at launch." We recommend that NASA conduct this type of planning to mitigate other forms of localized air pollution as well.

While the direct effects of acid precipitation have been discussed, secondary effects which have only recently come to light have not been mentioned. Evidence exists in the U.S. and Scandinavian countries that the occurence of trace metals in streams and lakes is attributable to the increased acidity of the water. This increased acidity results in the leaching of trace metals from the surrounding soil. The absence of any discussion concerning this phenomena suggests that an assessment of this kind of impact has not been made. Reference may be made to a number of sources. However, Gene E. Likens, "Acid Precipitation," Chemical Engineering News, Vol. 54, November 22, 1976, cites studies in the U.S., Sweden, and Norway, which should be of interest.

The fourth paragraph on page 84 implies that NASA is actively seeking a nonchlorine booster in order to minimize possible environmental impacts associated with chlorine discharges into the stratosphere. If this is so, the document might more clearly indicate the direction and level of effort on this project.

The discussion (page 115) concerning the effect on marine life resulting from sonic booms appears to be a spurious one. The velocity of the sonic boom is not a function of the velocity of the shuttle. The strength of the shockwave may be increased by the speed of the shuttle but the propogation rate is limited to the sonic velocity in air. The velocity of the shuttle could, therefore, not be an issue with regard to initiating a shock wave within the ocean waters. The paragraph, therefore, appears to have simultaneously created and dispatched an irrelevant issue.

The DEIS should mention that additional unpredictable secondary environmental and health impacts, both beneficial and adverse, could result from technological advancements developed in conjunction with the space shuttle missions.

Sincerely,

Charles Custard

Charles Custard
Director
Office of Environmental Affairs

U.S. Department of Health, Education, and Welfare, Office of the Secretary, Washington, D.C.

Comment: Various environmental impacts could be reduced by taking them into consideration during the planning of launch dates. As stated on page 74, "Control of acidic rain in the general region of the launchsite can be achieved by the proper choice of meteorological conditions at launch." It is recommended that NASA conduct this type of planning to mitigate other forms of localized air pollution as well.

Response: It is NASA's intent to use this type of planning to mitigate potential air quality effects. A sentence has been added at the end of section 4.2.1.1.1(b) which reads as follows: "Whenever possible, launches will be made at times when the meteorological conditions favor minimum effects on air quality."

Comment: The secondary effects of acid rain (e.g., trace metals and changes in ground water) have not been adequately addressed.

Response: Acid rain from the Space Shuttle will be rare and localized to a small area. Significant secondary effects as seen from widespread low-level continuous acid rain are not expected. The last paragraph in section 4.2.1.1.2 has been revised to clarify this point by the addition of the following:

> Secondary effects of acid rain (trace metal and ground water changes) similar to those observed for widespread and continuous acid rain might occur, but the areal extent and duration of such effects are expected to be small and temporary because of the episodic nature of Shuttle-derived acid rain.

Comment: The direction and level of NASA work on nonchlorine boosters should be more clearly indicated.

Response: No further work specifically directed to this objective is now under way for the reasons stated in section 5.2.1. No change to the text has been made as a result of this comment.

Comment: The discussion concerning the effects of sonic boom on marine life appears to be spurious.

Response: The discussion as originally written was not clear. Three paragraphs have been added at the end of section 4.5.5.1 and read as follows:

> When the horizontal velocity of the Shuttle is less than the speed of sound in water, equivalent to Mach 4.4 in air, the sonic boom from the Shuttle will propagate into the water as an acoustic wave, whose peak pressure attenuates rapidly with

water depth (ref. 4-50). The pressure wave is reduced to about one-tenth of its surface amplitude at a depth of 6 to 9 m (20 to 30 ft); see reference 4-51.

When the horizontal velocity of the Shuttle exceeds Mach 4.4, the sonic boom will propagate into the water as a shock wave. The peak pressure associated with the shock wave is not affected by water depth but attenuates as it does in air.

The principal effect of the sound and shock waves on marine life is expected to be a startle reaction. Fish have been subjected to intense sonic booms of 27 500 N/m^2 (550 psf) without noticeable effects (ref. 4-52). The wave in these tests only lasted about 0.05 msec, much less than the 200-msec duration expected from the Space Shuttle. It is not known whether the difference in duration is significant.

Comment: The environmental impact statement should mention that additional unpredictable secondary environmental and health impacts, both beneficial and adverse, could result from technological advancements developed in conjunction with Space Shuttle missions.

Response: The text describes the long-term environmental benefits (section 7) and other considerations (section 9) which are expected to offset the potential adverse environmental effects of the Space Shuttle Program (section 6). The real extent of the benefits from future space efforts can scarcely be predicted because the applications of technology are constantly increasing. No change to the text has been made as a result of this comment.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER-77/754

NOV 8 1977

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A, ADA,
B, G,
M, W

77-11-09

NONE

Ref: A34837
(8-5-77)

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D. C. 20546

Dear Mr. Crow:

Thank you for your August 5, 1977, letter requesting our review and comments on a draft environmental statement for the Space Shuttle Program.

General

We assume that the extent of new facility construction and its impacts on ground and surface water, soils, vegetation and wildlife are covered in site-specific statements since only cursory treatment is given these subjects in this document.

Specific

2.4 Existing Environments
Threatened and endangered plant and animal species at Kennedy Space Center and Vandenberg Air Force Base should be specifically identified.

The location of Canaveral National Seashore should be shown on Figure 2-21, page 49.

The National Space Technology Laboratories in southwest Mississippi, where test firing of engines will be conducted, is a 13,000-acre area surrounded by a 125,000-acre acoustical buffer area inhabited only by livestock and wildlife. As the statement indicates, there should be no adverse environmental impacts resulting from the project in this area.

3. Relationship of the Space Shuttle Program to Land-Use Plans, Policies and Controls

Closure of Playalinda Beach, Canaveral National Seashore, during STS launch operations will significantly reduce recreational use. Playalinda Beach is the traditional beach area for north Brevard County and the access road to it provides a southern access to the Spessard Holland National Seashore. In 1979, operations will require the closing of this heavily-used beach area approximately 35 percent of the time. This will result in a loss of about 210,000 man-days of recreation use and detrimentally affect the recreational opportunities for the citizens of north Brevard County and vicinity.

The statement is very explicit as to the environmental impact of the launch on the immediate area and the necessity for closing the adjacent beach areas during the launch period. It also points out the recreational value of observing the launch from other nearby locations and how such values may well outweigh the loss of beach use during that period. The statement does not, however, adequately explain why it is necessary that the adjacent beach areas, such as Playalinda Beach, have to be closed for extended periods of time (as much as 30 days) while the space shuttle vehicle is on the pad. The statement should more clearly discuss the impact of closure of recreational use at Playalinda Beach.

4. Possible Environmental Effects of the Space Shuttle Program

On page 74, the statement that pH values of 1 and 2 correspond to the acidity of normal human stomach fluids is irrelevant with respect to acidic rain and has the effect of glossing over the seriousness of acid rains.

The discussion in Section 4.6.8 provides some data on the effect of in-flight failures but stops short of assessing the environmental effects. It would be desirable to either indicate a range of potential effects or explain why this cannot be done.

The section on page 141 should be expanded to include a discussion of Canaveral National Seashore and that the National Park Service, not the Fish and Wildlife Service, manages Playalinda Beach.

6. Potential Unavoidable Adverse Environmental Effects
Measures to mitigate adverse environmental impacts are mentioned here and in earlier chapters. We recommend that a complete, separate list and discussion of committed mitigating measures be developed in the final statement.

We hope these comments will be useful to you in the preparation of the final statement.

Sincerely,

Larry E. Meierotto
Deputy Assistant SECRETARY

U.S. Department of the Interior, Office of the Secretary, Washington, D.C.

Comment: It is assumed that new facility construction and its impacts are covered in detail by the site-specific statements.

Response: Detailed descriptions of the construction, modification, and operation of support and manufacturing facilities at which major Space Shuttle activities will occur have been presented in the individual site-specific environmental impact statements (refs. 1-2 to 1-9). The KSC institutional statement is currently being updated. No change to the text has been made as a result of this comment.

Comment: Threatened and endangered plant and animal species at KSC and VAFB should be identified.

Response: The site-specific environmental impact statements contain this information (refs. 1-5 and 1-9). The KSC site-specific statement is currently being updated. It was felt that repetition of this information in the program statement would only add bulk to the document. No change to the text has been made as a result of this comment.

Comment: The location of Canaveral National Seashore should be shown.

Response: Figure 2-21 has been changed to show the location of the Canaveral National Seashore.

Comment: There should be no adverse environmental impacts resulting from test firing of engines at the NSTL.

Response: No response is required.

Comment: The statement does not adequately explain why it is necessary to close Playalinda Beach, Canaveral National Seashore, for extended periods (up to 30 days) while the Space Shuttle vehicle is on the launch pad.

Response: The text has been modified to clarify closure of Playalinda Beach. The following paragraph has been added at the end of section 4.7.3.5:

> During development and testing, State Route 402, which is the present access to Playalinda Beach, will be closed for a period of up to 30 days. During the launch of certain space vehicles safety and security measures have historically required closure of Playalinda Beach for periods of up to 4 months. The NASA safety and security measures are designed to cope with covert/overt penetrations and to prevent damage to flight hardware and

to launch support facilities. The period of closure associated with the Space Shuttle depends on the assessment of alternatives for the Canaveral National Seashore (ref. 10-3). This could result in closure of the entire Playalinda Beach or only of its southern portion up to 35 percent of the time during the operational phase of the Space Shuttle.

Comment: The statement that the pH values of 1 to 2 correspond to the acidity of normal human stomach fluids is irrelevant to acid rain.

Response: The intent was to provide an example of the degree of acidity, not to gloss over the subject. The third paragraph in section 4.2.1.1.2 has been modified to read as follows:

To gain a qualitative sense of the degree of acidity represented by these pH values, it may be helpful to note that the pH of vinegar is about 3.1 and that the pH of normal human stomach fluids is in the range of 1 to 2.

Comment: The discussion of in-flight failures (section 4.6.8) does not provide an assessment of the environmental effects.

Response: An assessment of the effect of inflight failures has been done, and the text has been modified accordingly. The following paragraph has been added to section 4.6.8.1:

In order to assess the impact of in-flight failures, it was assumed that the maximum possible amount of toxic material was released into the sea, and the volume of water required for dilution to the MAC was calculated. Results for MMH, nitrogen tetroxide, hydrazine, ammonium perchlorate, and hydrogen chloride were as follows:

Chemical compound	Affected vol. of seawater, liters	Dimension of cube containing affected volume, meters
MMH	3.8×10^9	156
Nitrogen tetroxide	8.3×10^7	44
Hydrazine	9.6×10^8	99
Ammonium perchlorate	1.4×10^{10}	240
Hydrogen chloride	*5.9×10^{11}	*830

*Dilution to pH = 5, neglecting the buffering capacity of eawater.

A qualitative sense of the potential size of the region affected by an in-flight failure is given by the last column in the table, which expresses the linear dimension of a cube containing the affected volume. Small schools of fish could be affected, but no large-scale or permanent effects on marine life are expected. These compounds are all chemically active and are not expected to persist in the marine environment.

Comment: Section 4.7.3.5 should be expanded to include a discussion of the Canaveral National Seashore.

Response: Section 4.7.3.5 has been changed to include the following:

A National Park Service study of all coastlines along the Atlantic Ocean and the Gulf of Mexico identified the Cape Canaveral and Mosquito Lagoon region as one of the prime remaining areas for providing public seashore recreational opportunities. Public Law 93-626 established the Canaveral National Seashore, which will include some 27 068 hectares (67 000 acres).

Under agreement with the U.S. Fish and Wildlife Service, the boundaries of the Merritt Wildlife Refuge and KSC are coextensive. This agreement provides that the U.S. Fish and Wildlife Service, subject to enumerated conditions, shall have primary administration over all property not related to the space program. In addition, 16 592 hectares (41 000 acres) of submerged and fast land owned outright by or otherwise obligated to NASA for operation of KSC are encompassed in the Canaveral National Seashore. Of these 16 592 hectares, 2693 hectares (6655 acres) are part of the national seashore administered by the National Park Service; and 13 899 hectares (34 345 acres) are part of the Merritt Island National Wildlife Refuge.

Comment: It is recommended that a separate list of committed mitigating measures be included in the final statement.

Response: Specific mitigation measures that are planned to circumvent environmental impacts are described throughout the text. No change to the text has been made as a result of this comment.

DEPARTMENT OF STATE

Washington, D.C. 20520

ADA-1
A, ADA,
AA, AC,
B, G, M

A34837

October 18, 1977

10-21-77

NONE

Filed with 8-5-77
Long

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Mr. Crow:

Officials in the Department of State have reviewed the draft Environmental Impact Statement on the Space Shuttle Program. While the statement addresses most major areas of the Department's interest, several suggestions on the statement were made which might be further developed in the final statement.

Among them was the recommendation that there be fuller discussion of the socio-economic impact of a cutback in the production of expendable launchers. Also, on page 89, last paragraph, there is a statement that liquid propellants may be used to replace solid propellant boosters, giving hope that the ozone layer will be able to recover soon. It would be valuable to indicate here what are the current activities and prospects for developing liquid propellant alternatives; otherwise the suggestion that they may be used would be misleading.

In addition, the alternatives section might usefully consider the option of launching all shuttles from either the Kennedy Space Center or from Vandenberg Air Force Base. Alternative mission profiles, orbital inclination for example, might well be examined in the statement.

We appreciate the opportunity to comment on the space shuttle statement.

Sincerely yours,

~~Bill L. Long~~
Acting Director
Office of Environmental Affairs

U.S. Department of State, Office of Environmental Affairs, Washington, D.C.

Comment: There should be more discussion of the socio-economic impact of a cutback in the production of expendable launchers.

Response: Employment in the aerospace industry has always been characterized by government and industry teams working together on long- and short-term projects. When projects end, contractor and government personnel are reassigned; or in some cases they find new employment opportunities, usually made available by manpower needs of new NASA or DOD programs. During periods of level NASA spending, which is now typical, adequate new job opportunities are expected to develop for personnel participating in programs that are being phased out. Where possible, the personnel associated with the expendable vehicle programs will be phased into other space program activities. In some cases, personnel may seek employment in nonspace-related areas, primarily because of the desire not to relocate. The text in section 4.7.2 has been expanded to include a discussion of this subject, as follows:

> The operational phase of the Space Shuttle Program is scheduled to begin in 1980, when the Space Shuttle is expected to begin replacing a large share of the expendable vehicle flights. Except for the large changes which took place when the Apollo Program was completed, it has been possible to reassign most contractor and government personnel to new aerospace activities when NASA programs have been phased down. Currently, many expendable launch vehicle contractors are involved in the Space Shuttle Program, and it is expected that the increased level of space operations made possible by the Space Shuttle will result in the reassignment of many of these workers to Shuttle payload-related activities. In some cases, personnel may seek employment in nonspace-related areas, primarily because of a desire not to relocate.

Comment: Section 4.2.2.4.1 states that liquid propellants may replace the solid propellant boosters, hence reducing the effects on the ozone layer. A statement of current activities and prospects for liquid propellants would be appropriate.

Response: The paragraph in section 4.2.2.4.1 referred to left an erroneous impression that the conclusion was based upon substituting an alternate booster system. This is not the case, and the paragraph has been deleted from the text except for pertinent information that is now included in the previous paragraph. Current activities for alternate systems are discussed in section 5.2.

Comment: Different mission profiles and launching all shuttles from KSC or VAFB could be included in the alternatives section.

Response: The alternatives suggested are not now considered viable STS options. The Shuttle configuration with the recoverable SRB's and the expendable External Tank limit launchsites to coastal locations.

U.S. Department of State, Office of Environmental Affairs, Washington, D.C. (continued)

In 1972, the Space Shuttle Launch and Recovery Site Review Board chose KSC and VAFB as the launchsites. Two launchsites are required to accommodate the wide variety of space missions (various altitudes and orbital inclinations) that will be undertaken by the Space Shuttle. Range safety constraints require that polar and sun-synchronous missions be conducted from VAFB and that near-equatorial, geosynchronous, and planetary missions be conducted from KSC. The alternative of flying the Space Shuttle from only one launchsite implies that expendable vehicle programs would be maintained at the other launchsite. The alternative of using only expendable launch vehicles is described in section 5.4. The KSC and VAFB site-specific Space Shuttle environmental impact statements (refs. 1-5 and 1-9) provide a historical perspective of launchsite selection. No change to the text has been made as a result of this comment.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS
COMMANDER(mep)
ELEVENTH COAST GUARD DISTRICT
UNION BANK BLDG.
400 OCEANGATE
LONG BEACH, CA. 90822
•Phone: FTS-984-9301

16475

NOV 23 1977

Space Shuttle Program
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Mr. Wetzel:

Per our phone conversation of 9 November 1977 the Draft Environmental Impact Statement (EIS) for the Space Shuttle Program dated July 1977 has been reviewed. As this Draft EIS was requested only because it was referenced in the Draft EIS on the Proposed Space Shuttle Program at Vandenberg Air Force Base (VAFB) prepared by the Air Force (AF); the following comments represent concerns not previously expressed. For your information a copy of our comments to the AF is enclosed.

On page 122 section 4.6.2.2.1- Recovery of the Solid Rocket Booster, the last sentence, "The retrieval vessel does not carry toxic or dangerous materials", is in error. All power driven vessels, regardless of cargo, carry toxic and/or dangerous materials as fuel. It is therefore recommended that this sentence be deleted or rewritten.

The opportunity to comment on this Draft EIS is appreciated.

R. C. HERTICA
Captain, U. S. Coast Guard
Chief, Marine Safety Division
By direction of the District Commander

Encl: (1) CCGD11 (mep) ltr 16475 dtd 12 OCT 77

Copies to (w/o Encl.):

COMDT(G-WEP-7/73)
CEQ (5 copies)
TES-70
DOT SEC REP (San Francisco)
SAF/MIO

U.S. Department of Transportation, United States Coast Guard, Marine Safety Division, Long Beach, California

Comment: The statement in section 4.6.2.2.1 that "The retrieval vessel does not carry toxic or dangerous materials" is in error.

Response: The retrieval vessel itself will be powered by ordinary petroleum-based fuels. The text in section 4.6.2.2.1 has been revised as follows:

> SRB impact will occur in a predicted elliptical zone about 18 x 60 km (11 x 38 miles). Warnings are provided to aircraft and ships before the launch, and the predicted impact area is maintained under surveillance. The recovery vessel is posted at a safe distance from the impact area; SRB impact on a vessel is thus highly improbable. The empty SRB is effectively inert. It will contain a small amount of residual hydrazine in tanks designed to withstand the splashdown loads and the salt water environment without leakage. Early SRB's will carry a linear shaped charge as part of the flight termination system for range safety; however, this ordnance will be both mechanically and electrically "safed" (made inert) prior to SRB separation. If the SRB should sink in deep water, no hazard would be presented to shipping or to the marine environment. If the SRB should sink in shallow water, it would be recovered because of its value. Hence, no hazard would result to either ships or to the environment. Mishaps to the retrieval vessel will not result in any environmental consequences different from those associated with any shipping mishap (excluding oil tankers). The retrieval vessel is powered by ordinary petroleum-based fuels. Normal safety precautions will be observed in handling these fuels.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

12 OCT 1977

OFFICE OF THE ADMINISTRATOR

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Mr. Crow:

This letter provides comments on your Administration's July 1977 draft Environmental Impact Statement (EIS) for the Space Shuttle Program. The preparation of this statement documents the additional information which has been developed of environmental concern regarding your program since its description in the initial statement of 1972. This Agency commends NASA for its efforts and will appreciate the opportunity to review and comment upon additional supplements or statements prepared as the space shuttle program enters it operational phase and more data is obtained concerning actual environmental impact.

Of particular interest is the impact of the program on atmospheric ozone levels. The statement (p. 84) reports that at full scale operations, 2,000 metric tons per year of Freon-113 will be released to the atmosphere during launching preparations which will reduce ozone levels by 0.04 percent with a value of 0.02 percent reached in about 50 years. To avoid this effect, it is requested that NASA continue to explore the use of closed-loop cleaning and recovery systems for Freon-113 as indicated on page 148 of the report. Of even greater concern is the 0.2 percent stratospheric ozone reduction predicted due to the chlorine in the solid propellant rocket motors from an estimated 60 launches per year. The statement (p. 89) notes that alternate low chlorine solid propellants are possible and non-chlorine containing liquid propellant boosters are feasible. It further estimates (p. 84) that, after an estimated 1992 conversion to a non-chlorine booster, the total duration of the 0.2 percent ozone reduction level would be about 10 years. Due to the potentially adverse environmental effects of an ozone

reduction, it is recommended that NASA continue its investigation to determine the actual effects of the program on stratospheric ozone levels and thus refine existing predictive models or develop improved new models. This will be helpful in making impact assessments for this and other programs. Increased efforts by NASA to develop and use space shuttle propellants which do not deplete ozone levels and which are cleaner burning than existing solid propellants are recommended.

The information provided by your latest statement is very helpful and the opportunity to review it is appreciated.

Sincerely yours,

Rebecca W. Hanmer
Director
Office of Federal Activities (A-104)

ADA-1
A-ADA-AA-
AC-6-
A34837 B-M
10-17-77
NONE
—
(Filed with 9/5/77 Corres.)

U.S. Environmental Protection Agency, Office of Federal Activities, Washington, D.C.

Comment: Concern was expressed over the impact of Freon-113, used in cleaning operations, on the ozone layer. It is requested that NASA explore the use of closed-loop cleaning and recovery systems for Freon-113.

Response: Section 5.3.2, Recovery System for Freon-113, has been revised to discuss NASA plans for Freon recovery as follows:

> Recovery of Freon-113 is a proven concept contributing to the reduction of emissions to the atmosphere. Significant reductions in the loss rate of Freon-113 during cleaning operations at the launch can be achieved by using closed-loop systems and recovery techniques to purify and reuse contaminated Freon-113. Three systems are involved in the current launchsite operation:
>
> 1. The launchsite cleaning laboratory uses Freon-113 to clean components removed from propellant handling systems at the launch pad. A system which reclaims approximately 139 kg (63 lb) per hour of the Freon-113 used in cleaning operations has been in use since the Apollo Program to recover Freon-113 at a low-volume rate.
>
> 2. To reduce the loss of Freon-113 in the cleaning laboratory, a system has been designed to reduce emissions to the air resulting directly from the cleaning operations. Freon vapor will be reclaimed at a rate of 2782 kg (1265 lb) per month from the air in the cleaning laboratory, beginning in 1979.
>
> 3. A construction project to provide a Freon reclamation facility capable of processing much larger quantities of Freon-113 is now under consideration. Use rates for the Space Shuttle Program will be larger than for prior systems, especially for the flush of launch pad oxidizer systems. These uses will exceed the capacity of the cleaning laboratory reclamation system by a large amount. The system is included in the 1979 construction and facilities budget as a separate line item.

Comment: Concern was expressed over the stratospheric ozone reduction expected from injection of Shuttle exhaust products into the stratosphere. It was recommended that NASA determine the actual effects of the Shuttle Program on stratospheric ozone and continue refinement and development of models to predict effects of Shuttle operation on the ozone layer.

U.S. Environmental Protection Agency, Office of Federal Activities, Washington, D.C. (continued)

Response: NASA has an extensive program of scientific research on the stratosphere to provide a solid basis for prediction of the effect of both the Space Shuttle Program and other programs on stratospheric ozone. An outline of the NASA program is provided in "Solar Terrestrial Programs. A Five-Year Plan" (ref. 10-4). A summary of current theoretical and experimental understanding of stratospheric ozone is provided in the NASA publication, "Chlorofluoromethanes and the Stratosphere" (ref. 10-5).

NASA plans to monitor stratospheric ozone both by remote measurements from satellites and by in situ measurements from balloon platforms.

NASA plans to extend these research and monitoring programs into the Shuttle operations period. No change to the text has been made as a result of this comment.

Comment: It was recommended that NASA increase its efforts to develop propellants that do not deplete the ozone layer.

Response: NASA has studied and tested a number of alternate propellants. The pros and cons of using alternate propellants are discussed in section 5.2 of the statement. Currently, there are no near-term plans to replace the existing propellants. Only modest study will continue on alternate boosters. No change to the text has been made as a result of this comment.

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Mr. Dave Hamernick
OEPAD
1700 W. Washington St.
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

This project is referred to you for review and comment. Please evaluate as to:

(1) the program's effect upon the plans and programs of your agency
(2) the importance of its contribution to State and/or areawide goals and objectives
(3) its accord with any applicable law, order or regulation with which you are familiar
(4) additional considerations

Please return THIS FORM AND ONE XEROX COPY to the clearinghouse no later than 17 working days from the date noted above. Please contact the clearinghouse if you need further information or additional time for review.

☐ No comment on this project
☐ Proposal is supported as written
☐ Comments as indicated below

Comments: (Use additional sheets if necessary)

There must be a more efficient way to communicate this environmental information to those with the technical expertise (and time) to review it. Thanks for the opportunity to comment even though I won't. This and the hundreds of other EIS's that are floating around make me wonder if anyone has time to review them and what is the impact of the whole process? The time period before NEPA seemed somewhat easier to comprehend as far as environmental issues were concerned, and I submit except for a few notable exceptions the planning was on just as solid a foundation as it is now.

Reviewer's Signature D. Hamernick

Date Sept 12, 1977

Title Planner

Telephone

State Clearing House, Arizona, Office of Economic Planning and Development, Phoenix, Arizona

Comment: Prior to NEPA, environmental issues were easier to comprehend and with a few exceptions, planning was on as solid a foundation as it is now.

Response: Section 102 (2) (C) of the National Environmental Policy Act (Public Law 91-190, 42 U.S.C. 4321 et seq.) and Executive Order 11514 (35 FR 4247, March 7, 1970) require that a detailed environmental statement be prepared on major Federal actions significantly affecting the quality of the human environment and that these statements be made available for comment. No change to the text has been made as a result of this comment.

TO:

Dr. James Becker
Center for Public Affairs
Arizona State University
Tempe, Arizona 85281

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

This project is referred to you for review and comment. Please evaluate as to:

(1) the program's effect upon the plans and programs of your agency
(2) the importance of its contribution to State and/or areawide goals and objectives
(3) its accord with any applicable law, order or regulation with which you are familiar
(4) additional considerations

Please return THIS FORM AND ONE XEROX COPY to the clearinghouse no later than 17 working days from the date noted above. Please contact the clearinghouse if you need further information or additional time for review.

☐ No comment on this project
☐ Proposal is supported as written
☒ Comments as indicated below

Comments: (Use additional sheets if necessary) The indirect effects of the Space Shuttle PROGRAM are quite different from those of Space Shuttle operations (p.v). Shuttle operation is a minor part, and has minor effect, as compared to the total PROGRAM effect. Consequently, an appraisal of the shuttle operation apart from program can be misleading. If all detachable parts are appraised separately, and if each receives judgment that its environmental impact is minor, then, even if all the parts are summed, the total program effect might be presented as minor. By reason, however, if program effects are minor, then why is the program executed? How could a judgment of "minor effect" be applied to a program which is initially justified for the GREAT effect it will have?

This is not an EIS on the Space Shuttle Program: it addresses shuttle operation alone.

If the total PROGRAM is judged to have extensive environmental effects, then an appraisal of any one of its parts APART from the program is a questionable practice.

Reviewer's Signature R. J. Becker

Date 9-7-77

Title Prof. Center for Public Affairs ASU

Telephone 965-3926

State Clearing House, Arizona, Center for Public Affairs
Arizona State University, Tempe, Arizona

Comment: The indirect effects of the Space Shuttle Program are quite different from those of Space Shuttle operations. Shuttle operation is a minor part and has minor effect, as compared to the total program effect. Consequently, an appraisal of the Shuttle operation apart from program can be misleading. If all detachable parts are appraised separately and if each receives judgment that its environmental impact is minor, then (even if all the parts are summed) the total program effect might be presented as minor. By reason, however, if program effects are minor, then why is the program executed? How could a judgment of "minor effect" be applied to a program which is initially justified for the great effect it will have? This is not an environmental impact statement on the Space Shuttle Program. It addresses Shuttle operation alone. If the total program is judged to have extensive environmental effects, then an appraisal of any one of its parts apart from the program is a questionable practice.

Response: This environmental impact statement addresses only the STS as stated in section 1.3. It is impractical to address all conceivable missions or cargoes associated with the program. The potential impact of these will be assessed as they are proposed. The most significant environmental effects of the Space Shuttle Program arise during the operational phase. For this reason, the overview emphasized the operational program. Impacts by other aspects of the program are covered in the body of the statement. No change to the text has been made as a result of this comment.

STATE OF NEVADA
GOVERNOR'S OFFICE OF PLANNING COORDINATION
CAPITOL BUILDING, ROOM 45
CAPITOL COMPLEX
CARSON CITY, NEVADA 89710
(702) 885-4865

September 29, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

RE: SAI NV #78800010 - NASA Space Shuttle Program

Dear Mr. Crow:

Thank you for the opportunity to reply on the above mentioned project. Attached are the comments of the State Clearinghouse as prepared by the Department of Conservation and Natural Resources/ Division of Environmental Protection.

These comments constitute the State Clearinghouse review of this proposal. Please incorporate these comments in your final decision.

Sincerely,

for Wallace W [illegible]
Bruce D. Arkell
State Planning Coordinator

BDA/pf

Enclosure

cc: Department of Conservation and Natural Resources/
Division of Environmental Protection

Action Copy to ADA-1
Info Copy to A, ADA, AA, AC, B, G, M
A34837

Rec'd in NASA 10-11-77

Suspense Date NONE

Interim Reply —

Signature of

filed with 8-5-77 corres

STATE OF NEVADA
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL PROTECTION
CAPITOL COMPLEX
CARSON CITY, NEVADA 89710

TELEPHONE: (702) 885-4670

September 9, 1977

SEP 1977

MEMORANDUM

TO: Steve Robinson

FROM: H. LaVerne Rosse *Verne*

SUBJECT: SAI NV #78800010, EIS Space Shuttle Program

Air Pollution (D. Serdoz): My review of the information contained in the July 1977 draft EIS for the Space Shuttle Program is that it is basically complete, with few exceptions. The information discussing the effect of pollutant concentrations was very informative and adequate. The units of measurement in one case did not follow the EPA normal nomenclature, i.e., mg/m^3 - µg/m^3. The exceptions that should be addressed in the final document are as follows:

1. A random sample of meteorological conditions were used to determine ambient air impacts. This concept should be modified using worst case, most probable, and average, meteorological conditions. These meteorological conditions should be determined by using at least five years of data near or at the launch and testing sites. I would prefer to see ten years of meteorological data for determining this information in order to be adequately certain that a normal six to seven year meteorological cycle was incorporated. When this is completed a set of meteorological conditions may have to be developed to prohibit firing on specific days to prevent significant ambient air impact from occurring.

2. The size distribution and counts for the soil such as aluminum oxide that are discharged from the firing of the propellents. My reason for my concern is that the document did not adequately discuss change or modification of weather conditions. The aluminum oxide size distribution and number of particulates per square centimeter can change an existing cloud formation from a marine type to a continental type. The difference in the formations is the size range and number of the water droplets. This may have an effect

on the weather condition in Nevada, once the firings start at VAFB. These emissions during firing may delay precipitation near the firing area and could help or hinder Nevada drought problems. These determinations may be made with the help of Dr. Robert I. Sax, with NOAR, and Dr. Joe Warburton at the University of Nevada, DRI.

Water Pollution (W. McCurry): No comment.

Solid Waste (H. Rosse): No comment.

gm

State of Nevada, Governor's Office of Planning Coordination, State Planning Coordinator, Division of Environmental Protection, Carson City, Nevada

Comment: It is pointed out that the impact statement on air quality was based on a random sample of meteorological conditions over 1 year. The suggestion is made that data for a period of 5 to 10 years be used to identify the worst, most probable, and average meteorological conditions to determine the impact on air quality as a result of a Space Shuttle launch. When this is completed, a set of meteorological conditions may have to be developed which would allow determination of days when Shuttle launches should be constrained to prevent occurrence of significant air quality impacts.

Response: NASA is in the process of performing parametric studies on air quality impact to identify worst-case conditions. Preliminary results do not indicate significant differences from the results given in the draft environmental impact statement. Another study is in progress to include data from an additional year. The year 1965 was selected because meteorological soundings were taken four times a day during that year, instead of the usual two times a day. The study simulates a launch a each of four times a day to determine diurnal effects and for every day of the year to determine seasonal effects. Results will be published at a later date. If these more extensive calculations indicate a need to constrain launch activities to favorable meteorological conditions, this mitigating action will be taken. No change to the text has been made as a result of this comment.

Comment: The discussion on weather modifications is inadequate, and the effects on Nevada are uncertain.

Response: The discussion is based on the best current information. NASA has studies in progress that should more adequately define possible inadvertent weather modifications. Measurements have been made of the launch cloud of two Titan launches which supplied data on aluminum oxide particle concentrations, size distribution, and efficiency for producing ice nuclei and cloud condensation nuclei. The preliminary data are not conclusive but there are indications that the cloud might be inactive for weather modification by ice nucleation. Further tests are planned. No change to the text has been made as a result of this comment.

STATE OF WASHINGTON
Dixy Lee Ray
Governor

OFFICE OF FINANCIAL MANAGEMENT
House Office Building, Olympia, Washington 98504 206/753-5450
Orin C. Smith, Director

October 5, 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Dr. Malkin:

Review of the draft environmental impact statement for the Space Shuttle Program has been completed by agencies of the State of Washington. The review was coordinated by the Office of Financial Management as the designated state clearinghouse.

Comments were received from the State Department of Transportation, Department of Game and Parks and Recreation Commission (see attached). The Department of Transportation's comment is highlighted below for your consideration.

The main concern of the Department of Transportation is the question of the environmental impact and probability of a mission abort with Oribiter landing at contingency locations other than Guam and Hawaii. The Department would appreciate being advised, no matter how low the probability of occurence, of any military and/or public airports in the State of Washington that are included in the contingency plans.

Thank you for the opportunity to review the statement. I hope you will find these comments useful in preparing the final statement.

Sincerely,

T Mahar

Tom Mahar
Assistant Director

TM:de

STATE OF WASHINGTON

Dixy Lee Ray
Governor

DEPARTMENT OF TRANSPORTATION
Division of Aeronautics

8600 Perimeter Road, Seattle, Washington 98108 Phone: 764-4131 — Toll Free 1-800-552-0666

William H. Hamilton, Director

September 26, 1977

RECEIVED
1977

Mike Mills
State Planning Division
Office of Financial Management
House Office Building
Olympia, WA 98504

Re: DRAFT - NASA - SPACE SHUTTLE PROGRAM

Dear Mr. Mills:

I have reviewed the Draft Environmental Impact Statement for the Space Shuttle Program dated July 1977. I can make no substantive comments.

However, the question of the environmental impact and probability of a mission abort with Orbiter landing at contingency locations other than Guam and Hawaii was not discussed. Are military and public airports in Washington (i.e. Fairchild Air Force Base or Grant County Airport) included in the contingency plans? If they are, no matter how low the probability of occurrence, the Division of Aeronautics would appreciate being advised.

Sincerely,

W. H. Hamilton
Manager of Aeronautics

WHH:bc

Game Commission
Claude Bekins, Seattle, Chairman
Glenn Galbraith, Wellpinit
Frank L. Cassidy, Jr., Vancouver
Arthur S. Coffin, Yakima
Elizabeth W. Meadowcroft, Tacoma
Archie U. Mills, Wenatchee

DEPARTMENT OF GAME

Director / Ralph W. Larson
Assistant Directors / Jack S. Wayland
John Douglas

600 North Capitol Way / Olympia, Washington 98504

August 30, 1977

RECEIVED
SEP 1

Mr. Mike Mills
State Planning Division
Office of Program Planning &
Fiscal Management
House Office Building
Olympia, Washington 98504

DRAFT EIS: NASA Space Shuttle Program

Mr. Mills,

Thank you for the opportunity to review this document. We have no comments.

Sincerely,

THE DEPARTMENT OF GAME

Chris Drivdahl

Chris Drivdahl, Applied Ecologist
Environmental Management Division

CD:cv

STATE OF WASHINGTON

Dixy Lee Ray
Governor

WASHINGTON STATE PARKS AND RECREATION COMMISSION
7150 Cleanwater Lane, Olympia, Washington 98504
206/753-5755

August 29, 1977

35-2650-1820

Draft EIS - NASA - Space
Shuttle Program

(E-1000)

TO: Mike Mills, State Planning Division, Office of Program Planning and Fiscal Management

FROM: David W. Heiser, E.P., Chief, Environmental Coordination

RE: DRAFT EIS - NASA - SPACE SHUTTLE PROGRAM

The Washington State Parks and Recreation Commission has reviewed the above-noted document and does not wish to make any comment.

Thank you for the opportunity to review and comment.

PJP:sg

RECEIVED
SEP 6 1977

State of Washington, Office of Financial Management,
Olympia, Washington

Comment: A concern was expressed over the question of Orbiter landing at contingency locations within the State of Washington.

Response: For the fourth through the sixth orbital test flights, Fairchild Air Force Base in Washington is a potential candidate for a contingency landing field in case of a mission abort. Discussions for contingency use of the Fairchild Air Force Base facilities are just now commencing through official channels. Fairchild Air Force Base is the only facility in the State of Washington under consideration as a contingency landing site. Selection of any contingency landing site will require agreement with local authorities. No change to the text has been made as a result of this comment.

CENTER FOR LAW AND SOCIAL POLICY

1751 N STREET N W WASHINGTON D C 20036 202 872 0670

James N Barnes
George C Deptula*
Roger S Foster
L Thomas Galloway
Marcia D Greenberger
Collot Guerard
Michael C Harper
Christine B Hickman
Carol J Jennings
Margaret A Kohn
J Davitt McAteer*
Leonard C Meeker
Marilyn G Rose
Lois J Schiffer
Herbert Semmel
Harvey J Shulman
Attorneys at Law
* Not admitted in D C

12 October 1977

ADA-1
A, ADA, AD, AC, B, G, M

A 34837

10-13-77

NONE

Filed with 8-5-77 comm

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

On behalf of the Friends of the Earth the comments below are submitted on the Draft Environmental Impact Statement for the Space Shuttle Program (July 1977). The careful consideration given the environmental consequences of the program is commendable. It is on the whole a well-done and comprehensive study, although there are two areas which require further explanation.

The section on employment impacts (p. 136) should also include discussion of plans and measures to be taken by NASA to insure reemployment opportunities for work forces associated with the project.

The section on the Space Shuttle missions for the 1980's (p. 31) should address the impacts of the missions themselves on the environment. Utilizing the Space Shuttle for launching solar sattelite stations, e.g., would have its own environmental impacts endependent of those from the launch. If NASA has not yet developed a definite space mission program, a separate programmatic EIS should be issued, which should also prove useful to NASA as a planning tool.

It should be emphasized that the general approval and commendation of this Draft EIS do not imply approval or support of the Shuttle Program as a whole, but only concern the quality of the EIA within the context of the planned Shuttle program.

Your response will be awaited with interest.

Sincerely,

Leonard C Meeker

Leonard C. Meeker

Don G. Scroggin

Dr. Don G. Scroggin

Center for Law and Social Policy, Friends of the Earth, Washington, D.C.

Comment: Section 4.7.2 (Employment Factors) should include a discussion of plans and measures to be taken by NASA to ensure reemployment opportunities for work forces associated with the Shuttle.

Response: In recent years, it has been possible to maintain an approximately steady level of employment in aerospace activities by reassignment of personnel to new programs as old ones are completed. The text in section 4.7.2 has been revised to expand on this, as follows:

> The operational phase of the Space Shuttle Program is scheduled to begin in 1980, when the Space Shuttle is expected to begin replacing a large share of the expendable vehicle flights. Except for the large changes which took place when the Apollo Program was completed, it has been possible to reassign most contractor and government personnel to new aerospace activities when NASA programs have been phased down. Currently, many expendable launch vehicle contractors are involved in the Space Shuttle Program, and it is expected that the increased level of space operations made possible by the Space Shuttle will result in the reassignment of many of these workers to Shuttle payload-related activities. In some cases, personnel may seek employment in nonspace-related areas, primarily because of a desire not to relocate.

Comment: The environmental impact of individual missions (e.g., Satellite Solar Power Stations) should be addressed in section 2.3.2.3.

Response: This statement is only for the development, manufacture, and operation of the STS (i.e., the Space Shuttle), as stated in section 1.3. It is not for any particular cargo or mission of the Space Shuttle. Should any specific cargo or mission be proposed for flight on the Space Shuttle, its potential environmental impact would be assessed; and if necessary, a separate impact statement would be written. The Satellite Power System represents a mission concept which is very early in its evolution, and its overall feasibility has not yet been established. No change to the text has been made as a result of this comment.

10.2 COMMENTS RECEIVED NOT REQUIRING NASA RESPONSE

All letters from the following agencies which did not elicit response from NASA are included in this section:

RECEIVED FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

SEP 1? ... AM '77

September 8, 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Dr. Malkin:

I am replying to your request of August 5, 1977 to the Federal Power Commission for comments on the Draft Environmental Impact Statement for the Space Shuttle Program. This Draft EIS has been reviewed by appropriate FPC staff components upon whose evaluation this response is based.

The staff concentrates its review of other agencies' environmental impact statements basically on those areas of the electric power and natural gas industries for which the Federal Power Commission has jurisdiction by law, or where staff has special expertise in evaluating environmental impacts involved with the proposed action. It does not appear that there would be any significant impacts in these areas of concern nor serious conflicts with this agency's responsibilities should this action be undertaken.

Thank you for the opportunity to review this statement.

Sincerely,

Jack M. Heinemann
Advisor on Environmental Quality

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

nsf

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ASTRONOMICAL.
ATMOSPHERIC. EARTH.
AND OCEAN SCIENCES

October 14, 1977

Mr. Duward L. Crow
Office of the Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

Several individuals in the National Science Foundation have reviewed the DEIS - Space Shuttle Program dated July 1977 and have no comments to offer.

Sincerely yours,

Daniel Hunt
Deputy Assistant Director
for Operations

ADA-1
A-ADA-
AA-AE-
B-G-M
A34837
10-17-77
NONE

Filed with 8/5/77 corres.

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

August 29, 1977

Action Copy to ADA-1
Info Copy to B, ADA, AA, AC, B, G, M
A34837
Rec'd in NASA 9-1-77
Response Date NONE
Prepare Reply for Signature of ___
Deal with 8-5-77 comms

Mr. Duward L. Crow
Associate Deputy Administrator
Office of the Administrator
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Mr. Crow:

This is in response to your request of August 5, 1977, for comments on the draft environmental statement (DES) for the National Aeronautics and Space Administration Space Shuttle Program.

The Council has reviewed the DES and notes that NASA has either demonstrated adequate compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470f, as amended, 90 Stat. 1320) or is fully aware of its responsibility pursuant to Section 106 with respect to the various project elements of the proposed undertaking.

Accordingly, we look forward to working further with NASA in accordance with the "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800) at the appropriate time.

Sincerely yours,

Michael H. Bureman
for Louis S. Wall
Assistant Director, Office
of Review and Compliance

The Council is an independent unit of the Executive Branch of the Federal Government charged by the Act of October 15, 1966 to advise the President and Congress in the field of Historic Preservation.

AGRICULTURAL RESEARCH SERVICE — OFFICE OF ADMINISTRATOR

OF UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D.C. 20250

September 9, 1977

Subject: Environmental Impact Statement, July 1977 Draft, Space Shuttle Program

To: Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D.C. 20546

A copy of the July 1977 draft of your environmental impact statement covering the space shuttle program has been sent to me for review for the Department of Agriculture.

The statement is in very good order and adequately covers the subject. There are no suggested changes.

Carl W. Carlson

Carl W. Carlson
Assistant Administrator
Soil, Water, and Air Sciences

Action Copy to ADA-1
Info Copy to A, ADA, AA, AC, B, G, M
A34837
[illegible] 9-14-77
[illegible] NONE

filed with 8-5-77 Corres

DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

August 31, 1977

Mr. Durward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

Thank you for giving the Agency for International Development the opportunity to comment on the Draft Environmental Impact Statement for NASA's Space Shuttle Program.

After a review of the document, we have identified no issues of direct environmental concern to AID or to the types of projects that AID sponsors in less developed countries.

I wish you all possible success in the remaining phases of the Program.

Sincerely yours,

Albert G. Printz, Jr.
Environmental Affairs
Coordinator

Action Copy to ADA-1
Info Copy to A, ADA, AA AC, B, G, M
A34837
Rec'd in NASA 9-6-77
Suspense Date NONE
Prepare Reply for
Signature of —

filed with 8.5-77 corres.

SIGNOFF

OMB Approval No. 29–R0218

FEDERAL ASSISTANCE

2. Applicant's application — a. Number: — b. Date: 19 Year Month Day

3. State Application Identifier — a. Number: AZ 77-80-0041 — b. Date Assigned: Year month day 19 77 09 02

Leave Blank: OCT 21 1977

1. Type Of Action (Mark appropriate box)
- ☐ Preapplication
- ☐ Application
- ☐ Notification Of Intent (Opt.)
- ☐ Report Of Federal Action

4. Legal Applicant/Recipient
- a. Applicant Name: National Aeronautics and Space Administration
- b. Organization Unit: Space Shuttle Program
- c. Street/P.O. Box:
- d. City: Washington
- e. County:
- f. State: D.C.
- g. Zip Code: 20546
- h. Contact Person (Name & telephone no.): Dr. Myron S. Malkin, Director, Space Shuttle Program (202) 755-3247

5. Federal Employer Identification No.

6. Program (From Federal Catalog)
- a. Number: 4 3 ● 9 9 9
- b. Title: Unknown

National Aeronautics and Space Administration

7. Title and description of applicant's project: SPACE SHUTTLE PROGRAM – DRAFT ENVIRONMENTAL IMPACT STATEMENT

Proposed action is continued development & follow-on operation of the Space Shuttle - a piloted, recoverable, reusable space transportation system for providing rapid, easy, and economical access to space. It will replace most of present expendable launch vehicles and will greatly expand the capability to carry out beneficial space activities. It is expected to make its first orbital test flight in 1979.

8. Type of applicant/recipient
- A–State
- B–Interstate
- C–Substate District
- D–County
- E–City
- F–School District
- G–Special Purpose District
- H–Community Action Agency
- I–Higher Educational Institution
- J–Indian Tribe
- K–Other

(Specify): Federal Agency — Enter appropriate letter: K

9. Type of assistance
- A–Basic Grant
- B–Supplemental Grant
- C–Loan
- D–Insurance
- E–Other

Enter appropriate letter(s): E

10. Area of project impact (Names of cities, counties, states, etc.): Statewide, Arizona

11. Estimated number of persons benefiting

12. Type of application
- A–New
- B–Renewal
- C–Revision
- D–Continuation
- E–Augmentation

Enter appropriate letter: A

13. Proposed Funding

a. Federal	$	.00
b. Applicant		.00
c. State		.00
d. Local		.00
e. Other	1	.00
f. Total	$ 1	.00

14. Congressional Districts Of: a. Applicant — b. Project

15. Type of change For 12c or 12e
- A–Increase Dollars
- B–Decrease Dollars
- C–Increase Duration
- D–Decrease Duration
- E–Cancellation
- F–Other Specify:

Enter appropriate letter(s)

16. Project Start Date Year month day 19

17. Project Duration Months

18. Estimated date to be submitted to federal agency Year month date 19

19. Existing federal identification number

20. Federal agency to receive request (Name, city, state, zip code)

21. Remarks added ☐ Yes ☐ No

Section II - Certification

22. The Applicant Certifies That
a. To the best of my knowledge and belief, data in this preapplication/application are true and correct, the document has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.

b. If required by OMB Circular A-95 this application was submitted, pursuant to instructions therein, to appropriate clearinghouses and all responses are attached:

	No response	Response attached
(1) Arizona State Clearinghouse	☐	☐
(2) Region I, III, IV, V, VI	☐	☒
(3) Region II	☒	☐

23. Certifying representative — a. Typed name and title — b. Signature — c. Date signed Year month day 19

Section III - Federal Agency Action

24. Agency name

25. Application received Year month day 19

26. Organizational Unit

27. Administrative office

28. Federal application identification

29. Address

30. Federal grant identification

31. Action taken
- ☐ a. Awarded
- ☐ b. Rejected
- ☐ c. Returned for amendment
- ☐ d. Deferred
- ☐ e. Withdrawn

32. Funding

a. Federal	$	.00
b. Applicant		.00
c. State		.00
d. Local		.00
e. Other		.00
f. Total	$	.00

33. Action date Year month day 19

34. Starting date Year month day 19

35. Contact for additional information (Name and telephone number)

36. Ending date Year month day 19

37. Remarks added ☐ Yes ☐ No

38. Federal agency A–95 action
a. In taking above action, any comments received from clearinghouses were considered. If agency response is due under provisions of Part 1, OMB Circular A-95, it has been or is being made.

b. Federal Agency A-95 Official (Name and telephone number)

424-101

Standard Form 424 Page 1 (10-75)
Prescribed by GSA, Federal Management Circular 74-7

ORIGINAL PAGE IS OF POOR QUALITY

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Mr. James R. Carter, Director
Agriculture & Horticulture Dept.
421 Capitol Annex West
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

RECEIVED
SEP 6 - 1977
ARIZONA COMMISSION OF AGRICULTURE & HORTICULTURE

This project is referred to you for review and comment. Please evaluate as to:

(1) the program's effect upon the plans and programs of your agency
(2) the importance of its contribution to State and/or areawide goals and objectives
(3) its accord with any applicable law, order or regulation with which you are familiar
(4) additional considerations

Please return THIS FORM AND ONE XEROX COPY to the clearinghouse no later than 17 working days from the date noted above. Please contact the clearinghouse if you need further information or additional time for review.

- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature James R. Carter

Date 9-6-77

Title Director

Telephone 271-4373

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Central Az. Ass'n of Gov'ts.
512 E. Butte Avenue
Florence, Arizona 85232

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamarnick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

This project is referred to you for review and comment. Please evaluate as to:

(1) the program's effect upon the plans and programs of your agency
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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature [signature]

Title [signature]

Date Oct 11, 1977

602
Telephone 868-5878

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO: SEP 8 1977

Mr. Roger Root, Acting Chief
Office of Planning
Dept of Econ. Security
1717 W. Jefferson
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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(4) additional considerations

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature [signature]

Date Sept 12, 1977

Title State Planner

Telephone 271-5884

Dr. Suzanne Dandoy, Director
Department of Health Services
1740 West Adams Street
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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Please contact the clearinghouse if you need further information or additional time for review.

- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature [illegible]

Date

Title

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Mr. Andrew L. Bettwy
Comm., Department of Land
1624 W. Adams St., 4th Floor
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

RECEIVED
SEP 6 1977
STATE LAND DEPT.
329

Comments: (Use additional sheets if necessary)

ORIGINAL PAGE IS
OF POOR QUALITY

Reviewer's Signature Mitchell T. Stellard

Date 9/1/77

Title Natural Resources Planner - Exchange

232

Telephone 271-3171

TO:

Vernon L. Hoy, Director
Dept. of Public Safety
P.O. Box 6638
Phoenix, Ariz. 85005

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

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☐ No comment on this project
☒ Proposal is supported as written
☐ Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature: [signature]

Date: 9 September 1977

Title: Lt. Colonel - Administration Bureau Chief

Telephone: 262-8011

Mr. Ronald D. McCready, Mgr.
Program Evaluation Section
Transportation Planning Division
Arizona Dept. of Transportation
206 South 17th Avenue, Room 310
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature Ronald D. McCready

Date [illegible]

Title

Telephone 261-7251

TO:

Mr. Frank Servin, Exec. Dir.
District IV Council of Gov'ts
377 South Main St., Room 202
Yuma, Arizona 85364

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick
Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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☒ No comment on this project
☐ Proposal is supported as written
☐ Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature ______ Date ______

Title ______ Telephone ______

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Mr. Robert Jantzen, Director
GAme and Fish DEpt.
2222 W. Greenway
Phoenix, Arizona 85023

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

ORIGINAL PAGE IS
OF POOR QUALITY

Reviewer's Signature: J. M. Cass

Date: 7 Sept 77

Title: Sch. Sv. Planning & Eval Br. 236

Telephone: 942-3000

To:

[illegible]
Executive Secretary
Indian Affairs Commission
1645 West Jefferson St.
Phoenix, AZ 85007

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
CEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

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☒ No comment on this project
☐ Proposal is supported as written
☐ Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature [illegible signature] Date 9/18/77

Title Telephone

TO:

John J. DeBolske, Exec. Dir.
Maricopa Ass'n of Governments
1820 W. Washington Street
Phoenix, AZ 85007

0716

State Application Identifier (SAI)			
SEP 2 1977	State AZ	No. 77-80-0041	

Economic Security — Health
Indian Affairs — Ag. & Hort.
Mineral Resources — Water
Game & Fish — Land
Public Safety — Parks
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

This project is referred to you for review and comment. Please evaluate as to:

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

RECEIVED
SEP
STATE CLEARINGHOUSE
OFFICE OF ECONOMIC
PLANNING & DEVELOPMENT

ORIGINAL PAGE IS
OF POOR QUALITY

Reviewer's Signature .... Date ....

Title .... Telephone ....

Mr. John Jett, Director
Mineral Resources Department
Fairgrounds, Mineral Building
1826 West McDowell Road
Phoenix, Arizona 85007

State Application Identifier (SAI)
SEP 2 1977 State AZ No. 77-80-0041

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

RECEIVED
SEP 7 1977
DEPT. MINERAL RESOURCES
PHOENIX, ARIZONA

This project is referred to you for review and comment. Please evaluate as to:

(1) the program's effect upon the plans and programs of your agency
(2) the importance of its contribution to State and/or areawide goals and objectives
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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature J. Jett

Title Director

Date 9-7-77

Telephone 271-3791

Northern Arizona Council of Governments

P.O. BOX 57 • FLAGSTAFF, AZ - 86001 • (602) 774-1895

WILLIAM C. WADE
EXECUTIVE DIRECTOR

Regional A-95 Review

TO: Ms. Jo Youngblood
Arizona State Clearinghouse
1700 W. Washington, Room 505
Phoenix, AZ 85007

RE: Project: National Aeronautics and Space Administration
Space Shuttle Program - DEIS
S.A.I. #: 77-80-0041

The Northern Arizona Council of Governments (NACOG) has completed its A-95 Review and Comment upon the above project. Action taken on this project notification is as follows:

☐ Proposal supported as described on the SF-424 and any attachments.

☐ Proposal is supported with certain recommendations, provisions, etc.

X No comment.

☐ Proposal is not supported.

Please be aware that NACOG reserves the prerogative of making additional comments should new information become available to the Agency.

The Northern Arizona Council of Governments has appreciated this opportunity to review and comment on this project.

Thank you.

William C. Wade
William C. Wade
Executive Director

Date: Sept. 20, 1977

THIS A-95 REVIEW IS SUPPORTED IN PART BY A HUD 701 PLANNING GRANT.

77-324 SEP 6 1977

Mr. David Landrith, Exec.
Director, SEAGO
118 Arizona Street
Bisbee, Arizona 85603

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

Economic Security
Indian Affairs
Mineral Resources
Game & Fish
Public Safety
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

Health
Ag. & Hort.
Water
Land
Parks

6 Regions

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature [signature]

Date 10/3/77

Title [illegible]

Telephone [illegible]

FORM TO BE COMPLETED BY REVIEWING AGENCY

TO:

Michael A. Ramnes, Director
Arizona State Parks Board
1688 W. Adams Room 109
Phoenix, Arizona 85007

State Application Identifier (SAI)

SEP 2 1977 State AZ No. 77-80-0041

Economic Security | Health
Indian Affairs | Ag. & Hort.
Mineral Resources | Water
Game & Fish | Land
Public Safety | Parks
Transportation
Environmental Studies
Renewable Natural Resources
Center for Public Affairs
Public Safety
OEPAD - D. Hamernick

6 Regions

From: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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- [x] No comment on this project
- [ ] Proposal is supported as written
- [ ] Comments as indicated below

Comments: (Use additional sheets if necessary)

Reviewer's Signature Allen Wagner   Date 9-8-77

Title RPII   Telephone 2714174

OFFICE OF THE SECRETARY
RESOURCES BUILDING
1416 NINTH STREET
95814
(916) 445-5656

Department of Conservation
Department of Fish and Game
Department of Navigation and Ocean Development
Department of Parks and Recreation
Department of Water Resources
Department of Forestry

EDMUND G. BROWN JR.
GOVERNOR OF
CALIFORNIA

NOV 22

Air Resources Board
Colorado River Board
San Francisco Bay Conservation and Development Commission
Solid Waste Management Board
State Lands Commission
State Reclamation Board
State Water Resources Control Board
Regional Water Quality Control Boards
Energy Resources Conservation and Development Commission
California Coastal Commission
California Conservation Corps
State Coastal Conservancy

THE RESOURCES AGENCY OF CALIFORNIA

SACRAMENTO, CALIFORNIA

NOV 16 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Dr. Malkin:

The State of California has reviewed the "Draft Environmental Impact Statement (DEIS), Space Shuttle Program, July 1977", which was submitted through the Office of Planning and Research (State Clearinghouse) in the Governor's Office. The review was in accordance with Part II of the U. S. Office of Management and Budget Circular A-95 and the National Environmental Policy Act of 1969.

The DEIS was reviewed by the Departments of Water Resources, Transportation, Food and Agriculture, Conservation, Fish and Game, and Parks and Recreation; the Energy Resources Conservation and Development Commission; the California Coastal Zone Conservation Commission; the Public Utilities Commission; the State Lands Division of the State Lands Commission; the Solid Waste Management Board; the Air Resources Board; and the State Water Resources Control Board.

The State has no comment to offer on this Environmental Impact Statement.

Sincerely,

L. FRANK GOODSON
Assistant Secretary for Resources

cc: Director of Management Systems
State Clearinghouse
Office of Planning and Research
1400 Tenth Street
Sacramento, CA 95814
(SCH No. 77092693)

STATE OF FLORIDA

Department of Administration

Division of State Planning

660 Apalachee Parkway · IBM Building

TALLAHASSEE

32304

(904) 488-1115

R. G. Whittle, Jr.
STATE PLANNING DIRECTOR

Reubin O'D. Askew
GOVERNOR

Lt. Gov. J. H. "Jim" Williams
SECRETARY OF ADMINISTRATION

October 6, 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Dr. Malkin:

Functioning as the state planning and development clearinghouse contemplated in U. S. Office of Management and Budget Circular A-95, we have reviewed the following draft environmental impact statement:

Space Shuttle Program (1977 Revision) SAI 78-0405E

During our review we referred the environmental impact statement to the following agencies, which we identified as interested: the Department of Community Affairs, the Department of Environmental Regulation, the Department of Natural Resources, and the Department of Transportation. Agencies were requested to review the statement and comment on possible effects that actions contemplated could have on matters of their concern. The reviewing agencies have not submitted comments to us regarding this program. We do not have any comments at this time, however, if further review finds that we have concerns on the document, we shall forward them immediately.

In accordance with the Council on Environmental Quality guidelines concerning statement on proposed federal actions affecting the environment, as required by the National Environmental Policy Act of 1969, and U. S. Office of Management and Budget Circular A-95, this letter should be appended to the final environmental impact statement on this project.

We request that you forward us copies of the final environmental impact statement prepared on this project.

Sincerely,

R. G. Whittle, Jr.
Director

RGWjr/WOK/ba

CC: Mr. Joseph W. Landers, Jr.
Mr. W. N. Lofroos
Mr. Loring Lovell
Mr. William Ravenell
Mr. Harmon Shields
Mr. Walter O. Kolb

STATE OF ILLINOIS
EXECUTIVE OFFICE OF THE GOVERNOR
BUREAU OF THE BUDGET
SPRINGFIELD 62706

September 27, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space
Administration
Office of the Administrator
Washington, D. C. 20546

Dear Mr. Crow:

RE: Environmental Impact Statement - Space Shuttle Program
Draft July, 1977, EIS #77-08-191

Pursuant to the National Environmental Policy Act (NEPA), OMB Circular A-95 (revised) and the administrative policy of the State, the referenced subject has been reviewed by the appropriate State agencies. No comments were made on the referenced subject.

Thank you for your assistance.

Respectfully,

T E Hornbacker J.W.

T. E. Hornbacker, Director
Illinois State Clearinghouse

/mc

ADA-1
A, AAG,
AA, AC,
B, G, M
A34837
10-3-77
NONE

filed with 8-5-77 cmes

Clearinghouse Use Only
St. Identification No.
7708540000
Date Received
8-15-77
Review Terminated
10-17-77

Indiana State Clearinghouse
State Budget Agency
212 State House
Indianapolis, Indiana 46204

AUTHORIZATION TO FILE APPLICATION

A0A-1
A, A0A,
AA, AC,
B, G, K

A 34837

10-21-77

NONE

Filed with 8-5-77 cons

TO: Mr. Duward L. Crow, Associate Deputy Administrator
National Aeronautics And Space Administration

PROJECT: EIS - Space Shuttle Program

Federal Program Title; Agency and FDA Catalog No.

Amount of Funds Requested

The State Clearinghouse has reviewed the summary notification pertaining to the above project. With regard to the summary notification, the Clearinghouse makes the following disposition concerning this application:

X The proposed project is in accord with State plans, goals, and objectives at this time.

___ Refer to the attached comments.

You may now complete and file your formal application with the appropriate Federal Agency. This form, with comments if any, is to be attached to that application, and the lower portion of this form is to be completed by you, detached, and returned to the State Clearinghouse when the formal application is submitted.

Sally Corn
Signature (Mrs. Sally Corn)

State Clearinghouse Reviewer
Title

October 17, 1977
Date

Indiana State Clearinghouse
State Budget Agency
212 State House
Indianapolis, Indiana

St. Identification No. 7708540000

The formal application for EIS - Space Shuttle (Name of Project) was submitted to the

___ on ___ by ___
Federal Agency | Date | Name of Applicant

Signature

/ADA-1

STATE OF KANSAS

Department of Administration

DIVISION OF STATE PLANNING AND RESEARCH
5th Floor--Mills Building
109 W. 9th
Topeka, Kansas 66612

October 10, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Re: Environmental Impact Statement
Space Shuttle Program
SAI Number 4868

Dear Mr. Crow:

The referenced project has been processed by the Division of State Planning and Research under its clearinghouse responsibilities described in Circular A-95.

After review by interested state agencies, it has been found that the proposed project does not adversely affect state plans. Enclosed are comments concerning this project for your information and referral.

Sincerely,

John Mendoza

John Mendoza
State A-95 Coordinator

JM:jc

ADA-1
A, ADA,
AA, AE,
B. G. M
10-14-77
NONE

Filed with 8-5-77 Comes.

NOTE: All future requests for A-95 review must be accompanied by seven copies of the application.

ORIGINAL PAGE IS
OF POOR QUALITY

STATE AGENCY A-95 TRANSMITTAL FORM

Return to:
Division of State Planning & Research, Department of Administration, Suite 501
Mills Building, Topeka, Kansas 66612

PROJECT TITLE: National Aeronautics and Space Administration Environmental Impact Statement

☐ Notification of Intent
☐ Final Application

DATE REVIEW PROCESS STARTED	DATE REVIEW PROCESS ENDED	SAI NUMBER
8-19-77	9-7-77	4868 - Environ

PART I Initial Project Notification Review (To be completed by Clearinghouse):

The attached project has been submitted to the State Clearinghouse under the provisions of the Federal OMB Circular A-95 revised. This form provides notification and opportunity for review of this project to the agencies checked below. Please fill in Part II and Part III below and return to the State Clearinghouse.

xx ☐ Return by 9-7-77
☐ Expedite
☐ Add. Info. Avail.

REVIEW AGENCIES

☒ Agriculture
☐ Budget Division
☐ Civil Rights Commission
☐ Criminal Administration
☒ Economic Development
☐ Education
☒ Health and Environment
☒ Historical Society
☒ KANS. CORP. COMM.
☐ Human Resources
☒ Park and Resources Authority
☐ Social and Rehabilitation Services
☐ Transportation
☐ Water Resources Board
☐ Regional Clearinghouse
☒ Forestry, Fish & Game Commission
☒ STATE CONSERVATION COMM.

AUG 29 REC'D

PART II Nature of Agency review comments (To be completed by review agency and returned to CH)

Check one or more appropriate boxes. Indicate comments below. Attach additional sheet if necessary or use reverse side.

☐ Request clarification or additional info.
☐ Suggestions for improving project proposal

COMMENTS:
This proposal should have no significant adverse impact on wildlife resources within the state of Kansas. Programs and activities of the Forestry, Fish & Game Commission will not be involved.

RECORDED
AUG 30 1977
DIVI ST. PLANNING & RESEARCH
By

PART III Recommended State Clearinghouse Action (To be completed by review agency and returned to Clearinghouse):

Check one box only:

XXXX ☐ Clearance of the project should be granted

☐ Clearance of the project should be delayed until the issues or questions have been clarified by the Applicant

☐ Clearance of the project should not be delayed but the Applicant should (in the final application) address or clarify the questions or concerns indicated above

☐ Request the opportunity to review the final application prior to submission to the federal funding agency

Jerry M. Conley	Forestry, Fish & Game	
Reviewer's Name	Div./Agency	Date Aug. 29, 1977

STATE AGENCY A-95 TRANSMITTAL FORM

Return to:
Division of State Planning & Research, Department of Administration, Suite 501
Mills Building, Topeka, Kansas 66612

PROJECT TITLE: National Aeronautics and Space Administration Environmental Impact Statement

☐ Notification of Intent
☐ Final Application

DATE REVIEW PROCESS STARTED	DATE REVIEW PROCESS ENDED	SAI NUMBER
8-19-77	9-7-77	4868 - Environ

PART I Initial Project Notification Review (To be completed by Clearinghouse):

The attached project has been submitted to the State Clearinghouse under the provisions of the Federal OMB Circular A-95 revised. This form provides notification and opportunity for review of this project to the agencies checked below. Please fill in Part II and Part III below and return to the State Clearinghouse.

☒ Return by 9-7-77
☐ Expedite
☐ Add. Info. Avail.

REVIEW AGENCIES

☒ Agriculture
☐ Budget Division
☐ Civil Rights Commission
☐ Criminal Administration
☒ Economic Development
☐ Education
☒ Health and Environment
☒ Historical Society
KANS. CORP. COMM.
☐ Human Resources
☒ Park and Resources Authority
☐ Social and Rehabilitation Services
☐ Transportation
☐ Water Resources Board
☐ Regional Clearinghouse
☒ Forestry, Fish & Game Commission
STATE CONSERVATION COMM.

PART II Nature of Agency review comments (To be completed by review agency and returned to CH)

Check one or more appropriate boxes. Indicate comments below. Attach additional sheet if necessary or use reverse side.

☐ Request clarification or additional info.
☐ Suggestions for improving project proposal

COMMENTS:
The proposed project should not adversely affect any identified historic or archeological resource, nor should it affect the goals or activities of this agency.

PART III Recommended State Clearinghouse Action (To be completed by review agency and returned to Clearinghouse):

Check one box only:

☒ Clearance of the project should be granted
☐ Clearance of the project should be delayed until the issues or questions have been clarified by the Applicant
☐ Clearance of the project should not be delayed but the Applicant should (in the final application) address or clarify the questions or concerns indicated above
☐ Request the opportunity to review the final application prior to submission to the federal funding agency

Richard Pankratz	Historical Society	9-6-77
Reviewer's Name	Div./Agency	Date

MARYLAND
DEPARTMENT OF STATE PLANNING

301 WEST PRESTON STREET
BALTIMORE, MARYLAND 21201
TELEPHONE: 301-383-2451

MARVIN MANDEL
GOVERNOR

VLADIMIR A. WAHBE
SECRETARY OF STATE PLANNING

August 12, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
NASA
Washington, D.C. 20546

SUBJECT: ENVIRONMENTAL HEALTH ADMINSTRATION

Applicant: National Aeronautics and Space Administration

Project: Draft EIS - Space Shuttle Program

State Clearinghouse Control Number: 78-8-153

State Clearinghouse Contact: James W. McConnaughhay (383-2467)

Dear Mr. Crow:

The State Clearinghouse has reviewed the above statement. In accordance with the procedures established by the Office of Management and Budget Circular A-95, it has been determined that the proposed project is not inconsistent with State plans, programs, and objectives as of this date.

Thank you for your attention to the A-95 review process and we lock forward to continued cooperation with your agency.

Sincerely,

Vladimir A. Wahbe

sda

Action Copy to ADA-1
Info Copy to A, ADA,
AA, AC,
A 34837 B, GE, M

Rec'd in NASA 8-17-77

Suspense Date NONE
Prepare Reply for
Signature of
Filed with 8-5-77 Corres

F/nC

OFFICE OF THE GOVERNOR
Planning & Coordination
1503 Walter Sillers Building
JACKSON, MISSISSIPPI 39201
354-7018

CLIFF FINCH
GOVERNOR

JAMES A FLEMING
DIRECTOR

STATE CLEARINGHOUSE FOR FEDERAL PROGRAMS

TO: National Aeronautics and Space
Administration
Washington, D. C. 20546

Attn: Duward L. Crow

State Clearinghouse Number

77081771

Date: October 4, 1977

PROJECT DESCRIPTION: -STATEWIDE-

Aeronautics and Space Administration (NASA) Space Shuttel Program

The State Clearinghouse, in cooperation with the state agencies interested or possibly affected, has completed the A-95 review of the project described above.

None of the state agencies involved in the review had comments or recommendations to offer at this time. This concludes the State Clearinghouse review, and we encourage appropriate action as soon as possible.

A copy of this letter is to be attached to the application as evidence of compliance with the A-95 requirements.

ADA-1
A, ADA,
AD, AC,
A 34837 B, G, M

10-7-77

NONE

John E. Gore, Jr.
Coordinator,
Clearinghouse For Federal Programs

filed with 8-5-77 corres 252

State of Missouri
OFFICE OF ADMINISTRATION
Jefferson City 65101

Joseph P. Teasdale
Governor

Gary O. Passmore, Director
Division of Budget and Planning

September 28, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

Subject: 77080140

The Division of Budget and Planning, as the designated State Clearinghouse, has coordinated a review of the above referred draft environmental impact statement with various concerned or affected state agencies pursuant to Section 102(2)(c) of the National Environmental Policy Act.

None of the state agencies involved in the review had comments or recommendations to offer at this time.

We appreciate the opportunity to review the statement and anticipate receiving the final environmental impact statement when prepared.

Sincerely,

George Lineberry

George Lineberry
Chief, Grants Coordination

ADA-1
A, ADA,
AA, AC,
A34837 B, L, M
10-4-77
NONE

filed with 8-5-77 Corres

ORIGINAL PAGE IS OF POOR QUALITY

STATE OF NEVADA
GOVERNOR'S OFFICE OF PLANNING COORDINATION
CAPITOL BUILDING, ROOM 45
CAPITOL COMPLEX
CARSON CITY, NEVADA 89710
(702) 885-4865

September 20, 1977

Action Copy to ADA-1
Info Copy to A ADA, AA, AE, 3, 4, 10
A34837
Rec'd in NASA 9-26-77
Suspense Date None
Prepare Reply for ——
Signature of ——
(filed w/8-5-77 ...)

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

RE: SAI NV #78800010 - NASA Space Shuttle Program

Dear Mr. Crow:

Thank you for the opportunity to review the above mentioned project.

The State Clearinghouse has processed the proposal and has no comment. Based on the information contained therein and the responses of interested parties, the proposed project is, as of this date, found not to be in conflict with the State's plans, goals, or objectives.

Sincerely,

Bruce D. Arkell
State Planning Coordinator

BDA/pf

State of New Jersey
DEPARTMENT OF COMMUNITY AFFAIRS

PATRICIA Q. SHEEHAN
COMMISSIONER

363 WEST STATE STREET
POST OFFICE BOX 2768
TRENTON, N.J. 08625

August 26, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

RE: OSRC-FY-78-133

Dear Mr. Crow:

In accordance with the U.S. Office of Management and Budget Circular A-95 Revised, your Environmental Impact Statement for a Space Shuttle Program designated application OSRC-FY-78-133 has met the State of New Jersey's Clearinghouse requirements.

We have circulated this Project Notification to the appropriate State agencies, none of which have voiced any objections.

Very truly yours,

Richard A. Ginman
Richard A. Ginman
State Review Coordinator

RAG:br

Action Copy to ADA-1
Info Copy to A.ADA
AA.AC
A34837 B.B.M.
Rec'd in NASA 9-7-77
Response Date NONE
[illegible] for
[illegible] of —
Filed w/8-6-77 corresp.

STATE OF NEW MEXICO

STATE PLANNING OFFICE

GREER BUILDING
505 DON GASPAR AVE.
SANTA FE 87503
(505) 827-2073

LEILA ANDREWS
STATE PLANNING OFFICER

JERRY APODACA
GOVERNOR

October 6, 1977

Dr. Myron S. Malkin, Director
Space Shuttle Program
NASA
Washington, D.C. 20546

Dear Dr. Malkin:

We have reviewed the draft environmental impact statement for the Space Shuttle Program and have no comment.

Thank you for the opportunity to review.

Sincerely,

Kate Wickes

Kate Wickes

KW:anne

North Carolina
Department of Administration
116 West Jones Street Raleigh 27603

James B. Hunt, Jr., Governor
Joseph W. Grimsley, Secretary

Division of Policy Development
Elmer Johnson, Administrator
(919) 733-4131

October 4, 1977

Mr. Duward L. Crow
Associate Deputy Adm.
National Aeronautics & Space Adm.
Washington, D. C. 20546

Dear Mr. Crow:

Re: SCH File No. 145-77; Draft EIS
Space Shuttle Program

The State Clearinghouse has received and reviewed the above referenced project. As a result of this review, the State Clearinghouse finds that no comment is necessary on this project at this time.

Sincerely,

Chrys Baggett

Chrys Baggett (Mrs)
Clearinghouse Supervisor

CB:mw

ADA-1
A, AIA,
AA, AC,
A34837 B, G, M
10-7-77
NONE

Filed with 8-5-77

August 31, 1977

STATE INTERGOVERNMENTAL CLEARINGHOUSE "LETTER OF CLEARANCE"
ON PROJECT REVIEW IN CONFORMANCE WITH OMB CIRCULAR NO. A-95

To: National Aeronautics and Space Administration

STATE APPLICATION IDENTIFIER: 7708179727

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

Subject: Draft Environmental Impact Statement by the National Aeronautics and Space Administration for the Space Shuttle Program - July, 1977.

This Draft EIS was received in our office on August 17, 1977.

In compliance with OMB Circular No. A-95, our office has reviewed this Draft EIS and hereby gives clearance to it without comment. The ND State Intergovernmental Clearinghouse requests the opportunity for complete re-review of applications for renewal or continuation grants or applications not submitted to or acted on by the funding agency within one year after the date of this letter.

Sincerely yours,

Bonnie A. Banks

Mrs. Leonard E. Banks
Associate Planner

LEB/ds

Action Copy to ADA-1
Info Copy to A/ADA, AA/AL, S, L, M

A34837

Rec'd in NASA 9-8-77

Suspense Date NONE
Prepare Reply for —
Signature of ——
Filed w/8-5-77 corresp.

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OF POOR QUALITY

ROBERT W. STRAUB
GOVERNOR

Executive Department
INTERGOVERNMENTAL RELATIONS DIVISION
ROOM 306, STATE LIBRARY BLDG., SALEM, OREGON 97310

October 12, 1977

Dr. Myron S. Malkin, Director
Space Shuttle Program
National Aeronautics and
Space Administration
Washington, D. C. 20546

Dear Dr. Malkin:

Re: Space Shuttle Program
PNRS 7708 4 1270

Thank you for submitting your draft Environmental Impact Statement for State of Oregon review and comment.

Your draft was referred to the appropriate state agencies. The consensus among reviewing agencies was that the draft adequately described the environmental impact of your proposal.

We will expect to receive copies of the final statement as required by Council of Environmental Quality Guidelines.

Sincerely,

Donald L. Jones
Administrator

DLJ:ts

OFFICE OF THE GOVERNOR

DOLPH BRISCOE
GOVERNOR

October 6, 1977

Mr. Durward L. Crow
Associate Deputy Administrator
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

The Draft Environmental Impact Statement, Space Shuttle Program has been reviewed by the Budget and Planning Office and interested State agencies

The comments of the reviewing agencies are enclosed for your use in the preparation of the final environmental impact statement. If this office can be of further assistance, please contact us.

Sincerely,

Roy Hogan

Roy Hogan, Assistant Director
Budget and Planning Office

Enclosures

A34837 ADA-1
A, ADA,
AA, AC,
B, G, M
10-12-77
NONE

filed with 8-5-77
cmts

EXECUTIVE OFFICE BUILDING • 411 WEST 13TH STREET • AUSTIN, TEXAS 78701

TEXAS AIR CONTROL BOARD

PHONE 512/451-5711
8520 SHOAL CREEK BOULEVARD
AUSTIN, TEXAS 78758

BILL STEWART, P. E.
EXECUTIVE DIRECTOR

September 7, 1977

RECEIVED

SEP 12 1977

Budget/Planning

Mr. Ward C. Goessling, Jr.
Natural Resources Section
Budget and Planning Office
Office of the Governor
411 West 13th Street
Austin, Texas 78701

Subject: Draft Environmental Impact Statement for the Space Shuttle Program, July, 1977

Dear Mr. Goessling:

We have reviewed the above cited document. We feel the operation of this project will be far enough from Texas so that there will be no significant adverse air quality effects in Texas.

Thank you for the opportunity to review this document. If we can be of further assistance, please contact me.

Sincerely yours,

Roger Wallis

Roger R. Wallis, Deputy Director
Standards and Regulations Program

Texas Department of Health

Fratis L. Duff, M.D., Dr.P.H.
Commissioner

Raymond T. Moore, M.D.
Deputy Commissioner

1100 West 49th Street
Austin, Texas 78756
458-7111

September 30, 1977

Mr. Charles D. Travis, Director
Governor's Budget and Planning
Office
Executive Office Building
411 West 13th Street
Austin, Texas 78701

ATTENTION: Ward C. Goessling, Jr., Coordinator
Natural Resources Section

SUBJECT: Space Shuttle Program
Draft Environmental Impact Statement
National Aeronautics and Space Administration

Dear Mr. Travis:

The Draft Environmental Impact Statement for the Space Shuttle Program dated July, 1977, has been reviewed for its public and environmental health implications. The statement provides a narrative account of the development of the Space Shuttle Program and a rationale for the use of the system for space activities. In our review of the Draft Environmental Impact Statement, no indication was found that take-offs or landings of space shuttle craft in Texas are proposed.

Section 4.4.6, "Summary of Acoustic Noise Effects on the Environment," and Sections 4.5.1 through 4.5.5 appear to adequately cover this Department's interest in adverse noise effects on the environment. Section 4.6, "Unplanned Events," adequately addresses other occupational health hazards.

Based on our review of the Draft Environmental Impact Statement, this Department does not anticipate adverse public or environmental health problems to result from the space shuttle program as proposed.

We appreciate the opportunity to review and comment on the Space Shuttle Program proposed by the National Aeronautics and Space Administration.

Sincerely,

Fratis L. Duff, M.D.
Commissioner of Health

AGENCY REVIEW TRANSMITTAL SHEET

TO: Dr. Fratis L. Duff, Texas Department of Health Resources — Date: Sent: 8/18/77

Date: Due: 9-30-77

FROM: CHARLES D. TRAVIS, BUDGET AND PLANNING OFFICE — Refer: EIS: 7-008-007

SUBJECT: DRAFT ENVIRONMENTAL IMPACT STATEMENT: SPACE SHUTTLE PROGRAM, JULY, 1977

We have reviewed the cited document and our comments as to the adequacy of treatment of environmental effects of concern are shown below:

	Check (X) for each item: None	Comment enclosed
1. Additional specific effects which should be assessed:	x	
2. Additional alternatives which should be considered:	x	
3. Better or more appropriate measures and standards which should be used to evaluate environmental effects:	x	
4. Additional control measures which should be applied to reduce adverse environmental effects or to avoid or minimize the irreversible or irretrievable commitment of resources:	x	
5. Our assessment of how serious the environmental damage from this project might be, using the best alternative and control measures:	x	
6. We identify issues which require further discussion or resolution:	x	

[x] This agency concurs with the implementation of this project.

[ ] This agency does not wish to comment on the subject document because:

David L. Houston

David L. Houston, P.E., Chief
Field Activities Branch
Division of Wastewater Technology
and Surveillance

Name and Title of Reviewing Official

Enclosure (s)

STATE OF WASHINGTON

Department of Natural Resources

COMMISSIONER
BERT COLE

DON LEE FRASER
SUPERVISOR

OLYMPIA, WASHINGTON
98504

September 6, 1977

Dr. Myron S. Malkin
Director, Space Shuttle Program
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Dr. Malkin:

SUBJECT: Environmental Impact Statement Draft - Space Shuttle Program

The draft environmental impact statement for the above-named subject has been reviewed by my staff. We have no comments regarding this proposal.

We appreciate having an opportunity to review this statement.

Very truly yours,

BERT L. COLE
Commissioner of Public Lands

Gerald D. Probst

Gerald D. Probst
Resource Planning Coordinator

GDP:em

WYOMING
EXECUTIVE DEPARTMENT
CHEYENNE

ED HERSCHLER
GOVERNOR

September 6, 1977

Mr. Duward L. Crow
Associate Deputy Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Crow:

Subject: Space Shuttle Program
Draft Environmental Impact Statement

The State Planning Coordinator's Office, serving as the State Clearinghouse, has received the above mentioned draft environmental impact statement. We have no comment at this time.

Please notify this office of the progress of the project.

Sincerely,

Richard M. Hartman (for)

Steve F. Freudenthal
State Planning Coordinator

SFF/br

Action Copy to ADA-1
Info Copy to A, ADA, AA, AE, B, L, M
A34837
NASA 9-12-77
None

Filed w/8-5-77 corresp.

APPENDIX A

ACRONYMS AND ABBREVIATIONS

ALT	approach and landing test
BHUV	biologically harmful ultraviolet
BSM	booster separation motor
CEQ	Council on Environmental Quality
CHBB	Committee on Hearing, Bioacoustics, and Biomechanics
CSD	Chemical Systems Division
CY	calendar year
dB	decibel
dB(A)	A-weighted decibel
DDT&E	design, development, testing, and evaluation
deg	degree
DFRC	Dryden Flight Research Center
DOD	Department of Defense
EAFB	Edwards Air Force Base
EPA	Environmental Protection Agency
ESA	European Space Agency
Freon-11	chlorotrifluoromethane
Freon-12	dichlorodifluoromethane
Freon-113	trichlorotrifluoroethane
FY	fiscal year
g/cm^3	gram per cubic centimeter
HMX	cyclotetramethylenetrinitramine
HTPB	hydroxy-terminated polybutadiene
ICAO	International Civil Aviation Organization
JSC	Lyndon B. Johnson Space Center
kph	kilometer per hour
KSC	John F. Kennedy Space Center
Leq	equivalent A-weighted sound level
MAC	maximum allowable concentration
MAF	Michoud Assembly Facility

MDAC	McDonnell-Douglas Astronautics Company
mg/m^3	milligram per cubic meter
min	minute
MMH	monomethylhydrazine
mph	mile per hour
msec	millisecond
MSFC	George C. Marshall Space Flight Center
NAS/NRC	National Academy of Sciences/National Research Council
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
nm	nanometer
NOAA	National Oceanic and Atmospheric Administration
NSTL	National Space Technology Laboratories
OMS	Orbital Maneuvering System
PBAN	polybutadiene acrylonitrile
PEL	public emergency limit
ppm	part per million
R&D	research and development
RCS	Reaction Control System
REED	rocket exhaust effluent diffusion
RSI	reusable surface insulation
sec	second
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
STP	standard temperature and pressure
STPL	short-term public limit
STS	Space Transportation System
TPS	Thermal Protection System
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
UTC	United Technologies Corporation
VAFB	Vandenberg Air Force Base

APPENDIX B

METRIC/ENGLISH CONVERSION FACTORS

To convert	into	multiply by
angstrom (A)	meter (m)	1.00×10^{-10}
atmosphere (atm) . . .	pound per square inch (psi)	14.70
celsius (°C)	Kelvin (K)	$t_K = t_C + 273.15$
Centigrade (°C) . . .	Fahrenheit (°F)	9/5C + 32
centimeter (cm) . . .	inch (in.)	0.3937
centimeter (cm) . . .	foot (ft)	3.281×10^{-2}
centimeter (cm) . . .	yard (yd)	1.094×10^{-2}
cubic meter (m^3) . . .	cubic foot (ft^3)	35.32
hectare	acre	2.471
hectare	square foot (sq ft)	1.076×10^{5}
hectare	square kilometer (sq km)	0.010
kilocalorie/kg (kcal/kg)	British thermal unit per pound (BTU/lb)	1.80
kilogram (kg)	pound (lb)	2.205
kilojoule (kJ)	Btu	0.948
kilojoule (kJ)	kilowatt hour (kWh)	2.778×10^{-4}
kilometer (km)	foot (ft)	3281
kilometer (km)	mile	0.6214
kilowatt (kW)	Btu/hr	3413
kilowatt (kW)	horsepower (boiler)	0.1020
liter	gallon (gal)	0.2642
liter	cubic foot (ft^3)	0.03531
meter (m)	inch (in.)	39.37
meter (m)	foot (ft)	3.281

To convert	into	multiply by
metric (m)	yard (yd)	1.094
metric ton	pound (lb)	2205
metric ton	ton	1.102
millibar (mb)	pound per square inch (psi)	1.451×10^{-2}
millibar (mb)	atmosphere	9.869×10^{-4}
milligram (mg)	pound (lb)	2.205×10^{-6}
Newton (N)	pound (lb_f)	0.2248
Newton per square meter (N/m^2)	pound per square foot (psf)	0.0209

APPENDIX C

ATMOSPHERIC DIFFUSION MODEL

If a gas is released in the atmosphere, it disperses by a process called diffusion. In the lower atmosphere, ambient winds and air turbulence determine the direction and speed of dispersal or diffusion of the gas. The process can be described by mathematical models useful for predicting launch cloud effects.

C.1 Cloud Diffusion Models

In principle, diffusion of a cloud can be predicted mathematically. The problem of predicting the dispersion of a pollutant released in the atmosphere becomes primarily that of determining the proper diffusion coefficient. Generally, this problem has been handled by defining broad classes of meteorological conditions (e.g., "stable," "neutral," and "unstable") and establishing empirical measures of the turbulent diffusion coefficient for each condition (refs. C-1 and C-2). However, if suitable meteorological measurements are available, these empirical measures can be related to more detailed features of the atmosphere. Over a period of years, the NASA/MSFC rocket exhaust effluent diffusion (REED) program (ref. C-2) has been developed to predict atmospheric dispersion of rocket effluents. The NASA/MSFC Multilayer Diffusion Model (refs. C-1 and C-2) used in the REED program is primarily kinematically dependent. The homogeneous layering of the atmosphere and definition of transport layers are based on the vertical kinematic and thermodynamic profiles. The cloud transport path is determined by the average wind velocity in each transport layer as obtained for the kinematic profile. The projected path can be computed if tetroonsonde data for winds aloft are available.

The initial problem, whose solution is particularly important for predicting the atmospheric dispersion of gases from static test firings, launches, and other hot releases, is defining the source; i.e., the initial distribution of the gases resulting from the buoyancy of the hot exhaust gases. Observation shows that the exhaust gases form a cloud elevated above the surface. A combination of theoretical analysis and empirical observations has been used to create a mathematical model of the cloud and thus to provide a source description for subsequent atmospheric dispersion analyses (refs. C-1, C-2, and C-6). However, one aspect of the source model may be subject to question and possible future revision: the distribution of the exhaust gases within the cloud. For the analysis used in this environmental assessment, the gases were assumed to have a Gaussian distribution. A uniform concentration within the cloud suggests itself as a plausible alternative to the Gaussian distribution, and exhaust cloud measurements made after Titan launches indicate that this type of distribution exists (ref. C-4). This situation is thought to arise as a result of the intense turbulent motion of the cloud, derived from the kinetic energy of the rocket exhaust, and the radial inflow of air at the base of the cloud as its buoyancy causes it to lift from the ground. Comparisons of the predicted downwind ground-level concentrations of exhaust gases using these two distributions have shown that the use of the Gaussian

distribution is conservative -- it results in higher predicted concentrations than the uniform distribution.

In addition to the meteorological parameters mentioned previously, which are the principal factors determining the turbulent diffusivity of the atmosphere, the depth of the surface transport layer or the presence of an inversion layer can profoundly affect the predicted ground-level concentrations of rocket exhaust gases. It is assumed that no transport of effluents occurs across the boundaries of a transport layer; hence, the effluents are trapped within their respective transport layers. Consequently, an interaction exists between the height of the surface transport layer and the height of the exhaust cloud stabilization in determining the downwind ground-level concentrations of exhaust gases.

C.2 NASA/MSFC Rocket Exhaust Effluent Diffusion Program for Predicting Exhaust Cloud Diffusion

The cloud diffusion predictions for this environmental assessment were calculated by the layering technique of the NASA/MSFC multilayer diffusion model in the REED program (ref. C-2) The layering technique both distributes the source and divides the ellipsoid source into homogeneous layers. The ground technique -- where the source is a whole ellipsoid -- was used extensively at NASA/KSC in real-time prediction of downwind concentrations of hydrogen chloride resulting from the launches of Titan (ref. C-7) and Delta (ref. C-8) space vehicles; and it generally gave relatively good agreement with measurements (ref. C-9). The ground technique was selected for real-time prediction primarily because it could be programmed on a desk-top programmable calculator and because it required less computational time than the layering techniques. Parametric investigations showed that both the ground cloud technique and the layering technique gave the same results when the surface transport layer was deeper than twice the height of exhaust cloud stabilization; then, the near-field results from the ground technique were higher than those obtained with layering techniques. This difference occurs because in the ground cloud technique, with shallow surface transport layers, the effective cloud rise height is equal to half the transport layer height; whereas in the layering technique, only the homogeneous layers below the top of the surface transport layer are used and kept at their natural altitude. Because sea breeze or temperature inversion commonly occurs at both KSC and VAFB, optimum results are obtained with the layering technique.

The combustion characteristics of the SRM propellant and meteorological conditions at the time of the release of exhaust constituents into the atmosphere are required as input to the NASA/MSFC cloud rise model (ref. C-2) to calculate the cloud rise and the initial source strength distribution of pollutants in the troposphere. The types of releases considered for analysis in the environmental assessment of the Space Shuttle Program are as follows: (1) open burning of waste SRM propellant, (2) normal static test firing, (3) abnormal static test firing, (4) accidental forward segment ignition, (5) accidental center segment ignition (ref. 1-6), (6) normal launch at KSC, (7) normal launch at VAFB, (8) abnormal launch at KSC, and (9) abnormal launch at VAFB.

The combustion of SRM propellant in all the types of releases considered in this environmental assessment results in the formation of a cloud of hot exhaust products which rises and entrains ambient air until an equilibrium with ambient conditions is reached. Previous cloud rise calculations (ref. C-3) for normal rocket launches, on-pad single SRM burns, and catastrophic failures have employed one of two cloud rise models -- the instantaneous or the continuous source cloud rise model. The instantaneous model has been used for normal launches and the continuous model for on-pad single SRM burns and catastrophic failures. The latter model is more conservative than the instantaneous model in that it predicts a lower cloud rise. All of the static test releases are of longer duration (quasi-instantaneous) than those which employ the instantaneous model and have dictated the use of the continuous source cloud rise model for calculations.

The inputs to the NASA/MSFC REED program, as previously mentioned, are meteorological information and the chemical composition and quantification in the stabilized ground cloud (i.e., the source and its strength). The meteorological information is fundamentally either a forecast or a rawinsonde sounding for the initial 6000-m (20 000-ft) of the atmosphere, with a 30-m (100-ft) resolution at the stabilized level. The specific parameters for air quality predictions are wind speed, direction and variability profiles, a virtual temperature profile, pressure profile, and surface density. Empirical models are currently used to obtain the wind variability in the azimuthal and elevational directions for the diffusion coefficients required for the model. Lagrangian information from tetroonsonde data or a mesoscale wind model can be used in the REED program to provide a more exact transport path.

The chemical composition of the stabilized ground cloud is obtained using thermochemical reaction models (refs. 4-3 and C-5) based on established rocket exhaust analytical techniques. In addition, the effects of afterburning are included.

C.3 Tests of the Cloud Diffusion Model

Since early 1972, NASA has been conducting effluent monitoring programs with selected NASA and USAF launches in Florida. The purpose of these monitoring programs is to develop a data base for assessing the NASA/MSFC REED program. The monitoring program focused on the Titan-III launch vehicle, which is currently the largest NASA SRM launch vehicle (about 40 percent of the size of the Shuttle). One Scout and numerous Delta vehicles were also monitored. To date, 20 launches have been monitored with varied degrees of measurement sophistication. The Titan-III monitorings typically consisted of both ground-level and airborne effluent measurements as well as measurements of the physical characteristics (volume, stabilization altitude, crosswind growth) of the exhaust effluent cloud formed at launch. Effluent measurements were of hydrogen chloride, particulate aluminum oxide, carbon monoxide, carbon dioxide, nitric oxide, and nitrogen oxides.

The maximum hydrogen chloride concentration measured at the surface (3 km or more from the launchsite) during Titan-III monitoring was 1.3 ppm.

The maximum total suspended particulate concentration was approximately 0.36 mg/m^3 close to the launchsite (less than 3 km), and it exists at this level for a few minutes at most (ref. 4-2). At distances from the launchsite greater than 10 km (6 miles), the total suspended particulate measurements are below 0.1 mg/m^3 (instantaneous high). In general, less than 20 percent of the measured total suspended particles was aluminum oxide; the remaining is attributed to ground debris.

Airborne measurements during the first 10 min within the stabilized ground cloud of the Titan-III launches resulted in hydrogen chloride concentrations generally within 1 to 6 ppm except for one case (40 ppm), in which portions of the cloud are thought to have been trapped between two layers of stable air and hence unable to diffuse normally.

The NASA/MSFC REED program was used to predict (using meteorological conditions at launch) the maximum surface level of hydrogen chloride and aluminum oxide concentration for the Titan-III launches monitored at the Eastern Test Range. The surface instrumentation was seldom located at the site of maximum predicted concentration because of the vagaries of the weather, nor could it be ascertained that the predicted locations of maximum concentration were exactly correct. In four of the launches monitored, however, the location of the surface instrumentation was near the region of predicted maximum concentration. In these cases, the ratio of the predicted maximum surface level concentration to the measured maximum concentration measured by the sampling network ranged from 1.2 to 16 for hydrogen chloride. In addition, the REED program was used to predict the maximum hydrogen chloride concentrations and dosages at specific instrument site locations. Table C-1 shows for four launches a comparison of the predicted to measured maximum concentration and dosage at a given site. As shown by table C-1, the concentration predictions using the model are high, on the average. This is to be expected at ground level, since the form of the diffusion model used did not include hydrogen chloride absorption at ground level by soil or plants.

The ratio of the predicted maximum surface level concentration to the measured maximum concentration measured by the sampling network for aluminum oxide ranged from 5 to 70. This was expected because the model in the form used does not allow for aluminum oxide deposition at ground level (similar to hydrogen chloride) and particle fallout. In addition, there is still some uncertainty in the aluminum oxide particle size distribution.

Work is continuing on improving the accuracy of the REED program, and the results presented here should be considered as preliminary. As it stands, the model is evidently a conservative one, predicting higher concentrations than are actually observed. This is a desirable direction for uncertainty in the model, since it leaves a large margin of safety.

TABLE C-1.-- MODEL/MEASUREMENT COMPARISONS

Launch	Number of comparison locations[a]	Ratio of predicted value to measured value				
		<0.1	0.1 to <1	1 to <10	10 to <100	<100
Maximum hydrogen chloride concentration at a given site location						
Dec. 1974	7	1	1	1	4	0
May 1975	9	0	1	4	4	0
Aug. 1975	10	0	1	4	4	1
Sept. 1975	9	0	1	3	4	1
Hydrogen chloride dosage at a given site location						
Dec. 1974	7	0	1	3	3	0
May 1975	9	0	0	5	4	0
Aug. 1975	10	0	0	5	5	0
Sept. 1975	9	0	1	3	5	0
Aluminum oxide dosage at a given site location						
Dec. 1974	8	0	1	4	3	0
May 1974	9	0	0	1	2	6
Aug. 1975	9	0	0	4	0	5
Sept. 1975	(b)	(b)	(b)	(b)	(b)	(b)

[a]Location of comparison sites ranges from 3 to about 20 km from the launchsite.

[b]Final data are not available at this time.

APPENDIX D

MODEL PREDICTIONS OF STRATOSPHERIC OZONE REDUCTION

D.1 Introduction

Chapman (ref. D-1) was the first to formulate the mechanism of ozone photochemistry in the upper atmosphere. His mechanism involves the photodissociation of molecular oxygen by solar ultraviolet radiation of wavelengths shorter than 2420 A (242 nm).

$$O_2 + h\nu \rightarrow 2O$$

Below 80 km (264 000 ft), the oxygen atoms react with molecular oxygen to form ozone by the three-body recombination:

$$O + O_2 + M \rightarrow O_3 + M$$

where M is any third body, mainly molecular nitrogen or oxygen. The ozone, in turn, can be photodissociated by solar radiation of wavelengths shorter than 3200 A and can also enter into a destruction reaction with atomic oxygen:

$$O_3 + h\nu \rightarrow O_2 + O$$

and

$$O_3 + O \rightarrow 2O_2$$

These sets of reactions, which transform solar radiation energy into thermal energy, are partly responsible for the temperature profile in the stratosphere.

In the steady state, the ozone concentration will be determined by a balance between the rate of ozone destruction (from photolysis and reaction with atomic oxygen) and the rate of ozone production (from reaction of atomic and molecular oxygen). The actual amount of ozone observed in the stratosphere is much less than would be expected from the simplified reaction scheme just outlined. This is explained by the existence of catalytic cycles for ozone destruction, as shown in the following example.

Ozone destruction:	$H + O_3 \rightarrow OH + O_2$
Catalyst regeneration:	$OH + O \rightarrow O_2 + H$
Net reaction:	$O + O_3 \rightarrow 2O_2$

The net reaction for ozone destruction in this case is much faster than the straightforward reaction of ozone with atomic oxygen, resulting in a decreased amount of ozone. A number of chemical compounds other than the hydrogen system just described can catalyze ozone destruction and decrease the steady-state ozone concentration. Nitrogen oxides and chlorine oxides are the other principal catalytic systems. Traces of these compounds introduced into the stratosphere can have significant effects on the ozone

concentration, which may last for several years because of the slow rate of diffusion out of the stratosphere down to the troposphere. Quantitative estimates of the ozone reduction produced by the addition of catalytic compounds to the stratosphere are made using theoretical models of the stratosphere.

D.2 Stratospheric Models

Models of the stratosphere incorporate two major factors: chemistry, the network of chemical reactions which involve stratospheric chemical species; and transport, the rate at which stratospheric gases move, both vertically and horizontally.

Studies of stratospheric chemistry have shown that the most important catalysts for ozone destruction can be grouped into three main chemical families: nitrogen oxide compounds, hydrogen oxide compounds, and chlorine oxide compounds. For example, the catalytic sequence for the chlorine oxide system is as follows:

Ozone destruction:	$Cl + O_3 \rightarrow ClO + O_2$
Regeneration of chlorine:	$ClO + O \rightarrow Cl + O_2$
Net reaction:	$O_3 + O \rightarrow 2O_2$

Similar reaction sequences can be written for the other catalytic compounds such as nitrogen peroxide. The families are not completely independent of one another. Reactions such as

$$NO + ClO \rightarrow Cl + NO_2$$

$$NO_2 + H \rightarrow NO + OH$$

$$ClO + NO_2 \rightarrow ClNO_3$$

$$NO_2 + HO_2 \rightarrow HO_2NO_2$$

link the groups together. Complete models for stratospheric chemistry include all these reactions plus the reactions of "source" compounds, (which produce the catalysts) and "sink" compounds (which remove the catalysts from the reaction system).

For a complete description of the stratosphere, transport processes must be included. Transport of chemical compounds in the stratosphere occurs both by molecular diffusion and by eddy diffusion characterized by winds and air turbulence. One-, two-, and three-dimensional stratospheric models include one, two, or three dimensions of mass transport.

One-dimensional stratospheric models consider only transport in the vertical direction. Horizontal transport (north/south and east/west) is neglected in these models. Because horizontal transport gradients are generally small over distances of tens to hundreds of miles, one-dimensional models are useful approximations. Two- and three-dimensional

models which include horizontal transport in one or two directions are currently being developed. Existing two-and three-dimensional models are suitable for large-scale estimations of the seasonal effects of horizontal global circulation but do not yet give local, detailed information.

D.3 Model Predictions of Space Shuttle Effects on the Ozone Layer

The models described can be used to estimate the effects of Space Shuttle stratospheric emissions on the ozone layer. Detailed discussions of the Shuttle effects are given in references 4-20 and D-4. A summary of information from these references is as follows. First, it is helpful to consider the relative importance of the exhaust emissions which could affect the ozone layer.

Water vapor and carbon dioxide are major products of Space Shuttle engine combustion. They are natural constituents of the stratosphere, and the amount introduced by the Space Shuttle exhaust is many orders of magnitude less than the existing amounts of these compounds. Aluminum oxide particles and oxides of nitrogen, chlorine, and hydrogen chloride require more detailed evaluation with respect to potential stratospheric effects.

The nitrogen oxide emission at the full rate of Space Shuttle operation is estimated to be 0.25×10^6 kg/yr. This is substantially less than the nitrogen oxide emission rate from a single supersonic passenger aircraft (of the Concorde class), which is approximately 0.9×10^6 kg/yr for near-continuous operation (ref. D-2). Nitrogen oxides are less efficient than chlorine oxides for ozone reduction. The total mass of chlorine compounds released by the Space Shuttle is about 13 times larger than the total mass of nitrogen oxides. It is reasonable, then, to conclude that any effect of nitrogen oxides would be 13 times smaller than chlorine effects.

Aluminum oxide particles can act as centers for ozone and atomic oxygen destruction; thus, the aluminum oxide particles from the Space Shuttle exhaust could reduce the stratospheric ozone concentration. Detailed chemical kinetic measurements and calculations of this effect have been done (ref. 4-20) with the result that aluminum oxide particle effects on ozone concentration are less than 0.001 percent.

Chlorine compounds (hydrogen chloride and chlorine) in the exhaust are left as the most significant exhaust products relative to ozone reduction. One-dimensional stratospheric models were used to evaluate the effect of chlorine compounds on the ozone layer. Because of the approximations which must be made, it is found that several different models exist, each based on slightly different approximations. These models are equivalent, but they yield different values for the Space Shuttle effects on the ozone layer. To evaluate Space Shuttle effects in the most general and impartial way, one-dimensional models developed by different scientific groups were used to calculate the hemispheric average reduction of stratospheric ozone by Space Shuttle emissions.

Since the models are one-dimensional, some initial assumption must be made concerning the distribution of exhaust products with latitude and

longitude. Because east/west distribution is fast whereas north/south distribution is slow in the stratosphere, the exhaust products of the Space Shuttle were assumed to be distributed only over the Northern Hemisphere; hence, the term "hemispheric average."

For preparation of the draft environmental impact statement, six independent calculations were made in late 1976, with the results listed in table D-1.

TABLE D-1.-- PREDICTED OZONE REDUCTION FOR 60 SPACE SHUTTLE LAUNCHES PER YEAR - 1976 MODELS

Modeling group	Ozone reduction (hemispheric average), %	Reference
NASA/Ames Research Center	0.11	4-20
University of Michigan	.29	4-20
Lawrence Livermore Laboratory	.26	4-20
NASA/JSC	.2	4-20
Harvard University	.2	4-20
National Academy of Sciences	.15	4-19

In 1977, the rate for the stratospheric reaction $HO_2 + NO \rightarrow OH + NO_2$ was revised upward (ref. D-4). The increased OH concentration resulting from this change leads to an increase in the amount of catalytically effective chlorine, from the reaction $OH + HCl \rightarrow H_2O + Cl$. As a result, the predicted ozone reduction effects for the chlorofluoromethanes are almost doubled. It was expected that the predicted Shuttle effect would also increase, perhaps by as much as a factor of 2. For this reason, the Shuttle effect has been recalculated.

Five independent calculations were made of the Shuttle effect on the ozone layer using the new reaction rate data. Details of their calculations are provided in reference D-4. Results are summarized in table D-2.

TABLE D-2 -- PREDICTED OZONE REDUCTION FOR 60 SPACE SHUTTLE LAUNCHES PER YEAR - 1977 MODELS

Modeling group	Ozone reduction (hemispheric average), %
NASA/Ames Research Center	0.28*
University of Michigan	.23
Lawrence Livermore Laboratory	.27
NASA/GSFC (JSC)	.26
NASA/Langley Research Center	.24

*Estimated for Northern Hemisphere average from two-dimensional global prediction.

The results are more consistent with one another than the previous calculation, with an average near 0.25 percent, to be compared with the previous value of 0.2 percent. The effect of the new reaction rate is much less for the Shuttle than for the chlorofluoromethanes because the new rate constant not only causes an increase in the amount of chlorine catalyst for ozone reduction, but also causes an increase of the calculated loss rate of exhaust gases from the stratosphere. (This comes about because the eddy diffusion coefficient from vertical profiles of methane concentration involves an estimate of the rate of methane oxidation by hydroxyl.) These two effects compensate in the case of the Shuttle.

The Northern Hemisphere average value from NASA/Ames Research Center was estimated from the Center's recent two-dimensional calculations, which gave the global distribution of ozone reduction. The Center found that "hemispheric average" assumption overestimated the Northern Hemisphere effects and underestimated the Southern Hemisphere effects. A global average whereby the ozone reduction occurs uniformly over the entire world rather than only in the Northern Hemisphere was a much better fit to the results.

Since the ARC calculations are still preliminary, it was thought best to retain for now the original "hemispheric average" assumption. However, it may prove necessary in the future to revise downward the predicted Shuttle effect, perhaps by as much as a factor of 2, if the validity of using a global average effect instead of a hemispheric average is verified.

The uncertainty of the predicted ozone reduction percentage is composed of two parts: systematic and random. The former depends on the

correct formulation of the model and is impossible to estimate quantitatively at this time. The ongoing NASA stratospheric research program (ref. D-3) is designed to establish the general validity of the models. The random errors are, however, susceptible to statistical analysis. Results of this type of analysis lead to the conclusion that at a 95-percent confidence level, the uncertainty is about a factor of 1.8 on the high side and 2.9 on the low side (ref. D-4).

The hemispheric average Shuttle ozone reduction can be assigned a nominal value of 0.25 percent. This value satisfactorily represents all the model results, well within the random error uncertainty limits.

The time dependence of the ozone reduction factor for the Space Shuttle exhaust is significantly different than for the chlorofluoromethanes. The Space Shuttle exhaust products are emitted directly into the stratosphere and diffuse out to the troposphere where they are washed down by rainfall; consequently, the exhaust product effects have time scales of several years. Chlorofluoromethanes accumulate in the troposphere and diffuse up to the stratosphere; time scales for their effects are of the order of tens to hundreds of years.

The predicted time dependence of the Space Shuttle ozone reduction is shown in figure 4-5 (ref. 4-17). The present mission model was used for the calculations shown in this figure. The time constant for decay of the Space Shuttle effect after termination of chlorine emission is 2 to 6 years, depending on the assumed value of the diffusion coefficient. The conclusion drawn from this calculation is that no permanent or long-lasting changes to the stratosphere will result from operation of the Space Shuttle.

APPENDIX E

REFERENCES

1-1. Environmental Statement for the Space Shuttle Program, Final Statement. NASA Headquarters, July 1972.

1-2. Final Environmental Impact Statement for Space Shuttle Main Engine Component and Subsystem Testing, Santa Susana, California. NASA/MSFC, Aug. 1973.

1-3. Final Environmental Impact Statement for the Overland Transport of the NASA Space Shuttle Orbiter between U.S. Air Force Plant 42, Palmdale, California, and the Dryden Flight Research Center/Edwards Air Force Base, California. NASA/JSC, May 1976.

1-4. Environmental Statement for the George C. Marshall Space Flight Center and Mississippi Test Facility (now National Space Technology Laboratory) -- Final Statement. NASA/MSFC, Oct. 1972.

1-5. Amendment 1 to the Institutional Environmental Impact Statement (Space Shuttle Development and Operations) -- Final Statement. NASA/KSC, June 1973. (Updating of this Statement is in progress.)

1-6. Final Environmental Statement for the Space Shuttle Solid Rocket Motor DDT&E Program at Thiokol/Wasatch, Promontory, Utah. NASA/MSFC, Jan. 1977.

1-7. Environmental Impact Statement for Manned Spacecraft Center (now Lyndon B. Johnson Space Center) and White Sands Test Facility. NASA/JSC, Feb. 1971.

1-8. Institutional Environmental Impact Statement, Michoud Assembly Facility, New Orleans, Louisiana. NASA/MSFC, Jan. 1978.

1-9. Final Environmental Statement, Space Shuttle Program, Vandenberg Air Force Base, California. USAF/SAMSO, Jan. 1978.

1-10. Cour-Palais, B. G., ed.: Proceedings of the Space Shuttle Environmental Assessment Workshop on Tropospheric Effects. NASA TM X-58199, Feb. 1977.

1-11. Potter, A. E., ed.: Proceedings of the Space Shuttle Environmental Assessment Workshop on Stratospheric Effects. NASA TM X-58198, Jan. 1977.

2-1. Space Shuttle. NASA SP-407, 1976.

2-2. Shaphell, W. G., Jr.; McCoy, H. E.; and Gray, R. H.: KSC Launch Site Accommodations Handbook for Launch Site Payloads. KSC Revision 2, K-SM-14, June 1975.

2-3. Salt Lake City, Utah Local Climatological Data, Annual Summary with Comparative Data. U.S. Dept. of Commerce, 1975.

2-4. Allen, Leerue; and Velasquez, Vern: Bear River Migratory Bird Refuge. U.S. Fish and Wildlife Service, Dec. 1975.

2-5. Climates of the States. Vol. 2. Water Information Center, Inc. (New York), 1974.

2-6. Greenfield, S: Climatological Summary of the Cape Canaveral, Merritt Island Area. NOAA-NUS, Jan. 1975.

2-7. Falls, Lee W.; Williford, W. O.; and Carter, M. C.: Probability Distributions for Thunderstorm Activity at Cape Kennedy, Florida. NASA TM X-53867, Marshall Space Flight Center, 1970.

2-8. U.S. Air Force: Environmental Narrative, Phase 1, Vandenberg AFB, Lompoc, California. July 15, 1975.

2-9. Livingston and Blayney: Santa Barbara County Comprehensive Plan: Conservation Element. Santa Barbara County, Aug. 1974.

3-1. Letter from Ann Webster Smith (Director, Office of Compliance, Advisory Council on Historic Preservation) to Mr. Monte D. Wright (Director, NASA Historical Office, Washington, D.C.), Apr. 8, 1974.

4-1. The Natural Stratosphere of 1974. CIAD Monograph 1, Sept. 1975.

4-2. Cour-Palais, B. G., ed.: Proceedings of the Space Shuttle Environmental Assessment Workshop on Tropospheric Effects. NASA TM X-58199, Feb. 1977.

4-3. Gomberg, R.; and Wilmoth, R.: Afterburning Processes Occurring Within the Solid Rocket Motor Plumes of the Space Shuttle Near the Launch Pad, 1977.

4-4. Federal Register. Vol. 36, no. 206, Oct. 23, 1971, p. 20513.

4-5. Smyth, H. F., Jr.: Military and Space Short-Term Inhalation Standards. Archives Environmental Health, Vol. 12, Apr. 1966, pp. 488-490.

4-6. National Primary and Secondary Ambient Air Quality Standards. CFR, Title 40, Ch. I, Pr. 50, rev. July 1, 1976.

4-7. Guides for Short-Term Exposures of the Public to Air Pollutants: II. Guide for Hydrogen Chloride. National Academy of Sciences/National Research Council Report No. APTD-0764, Aug. 1971.

4-8. Guides for Short-Term Exposures of the Public to Air Pollutants: VI. Guide for Carbon Monoxide. National Academy of Sciences/National Research Council Report No. NAS/ACT/P-628.7, Mar. 1973.

4-9. Guides for Short-Term Exposures of the Public to Air Pollutants: VIII. Guide for Chlorine. National Academy of Sciences/National Research Council Report No. NAS/ACT/P-628.9, Mar. 1973.

4-10. Guides for Short-Term Exposures of the Public to Air Pollutants: V. Guide for Hydrazine, Monomethylhydrazine, and 1, 1-Dimethylhydrazine. NAS/NRC Report No. NAS/ACT/P-628.6, June 1974.

4-11. Guides for Short-Term Exposures of the Public to Air Pollutants: I. Guide for Oxides of Nitrogen. NAS/NRC Report No. APTD-0667, Apr. 1, 1971.

4-12. Lerman, S.; Cooper, R.; Scherfig, J.; and Greenhouse, G.: Environmental Quality Research, First Annual Report. Univ. of California at Irvine, AMRL-TR-74-82, 1975.

4-13. Wohlslagel, J.; Di Pasquale, L. C.; and Vernot, E. C.: Toxicity of Solid Rocket Motor Exhausts - Effects of HCl, HF, and Alumina on Rodents, in Proc. 6th Annual Conf. Environ. Toxicology. Aerospace Medical Research Laboratories, AMRL-TR-75-125, Dec. 1975.

4-14. Darmer, K. I., Jr.; Kinkead, E. R.; and Di Pasquale, L. C.: Acute Toxicity in Rats and Mice Resulting from Exposure to HCl Gas and HCl Aerosol for 5 and 30 Minutes. AMRL-TR-72-21, Apr. 1972.

4-15. Stout, I. J.; et al.: Final Report to the National Aeronautics and Space Administration, Kennedy Space Center, Ecological Effects and Environmental Fate of Solid Rocket Exhaust, Third Annual Report. Florida Technological University, NGR-10-019-009, Jan. 1976.

4-16. Lerman, S.: The Phytotoxicity of Missile Exhaust Products: Short-Term Exposures of Plants to HCl, HF, and Al_2O_3. Atmos. Environ., Vol. 10, pp. 873-878, 1976.

4-17. Likens, G. E.; and Borman, F. H.: Acid Rain: A Serious Regional Problem. Science, vol. 184, 1974, pp. 1175-1179.

4-18. Mohnen, V.A.; et al.: Position Paper on the Potential of Inadvertent Weather Modification of the Florida Peninsula Resulting from the Stabilized Ground Cloud, Final Report. Institute on Man and Science (Rensselaerville, New York), Aug. 1976.

4-19. Halocarbons: Effects on Stratospheric Ozone. National Academy of Sciences (Washington, D.C.), Sept. 1976.

4-20. Potter, A. E., ed.: Proceedings of the Space Shuttle Environmental Assessment Workshop on Stratospheric Effects. NASA TM X-58198, Jan. 1977.

4-21. Nachtwey, S.: Medical/Biological Effects of Increased UV Radiation Resulting from O_3 Reduction, in Proceedings of the Space Shuttle Environmental Assessment Workshop on Stratospheric Effects. NASA TM X-58198, Jan. 1977.

4-22. Caldwell, M. M.; and Nachtwey, D. S.: Introduction and Overview. Chapter 1, CIAP Monograph 5, Impacts of Climatic Change on the Biosphere, Part 1, Ultraviolet Radiation Effects. DOT-TST-75-55, Sept. 1975.

4-23. Walter, H.: Vegetation of the Earth in Relation to Climate and the Eco-physiological Conditions. Trans. by Joy Wieser. Springer-Verlag, 1973.

4-24. Caldwell, M. M.; Sisson, W. B.; Fox, F. M.; and Brandle, J. R.: Plant Growth Response to Elevated UV Irradiation under Field and Greenhouse Conditions. Chapter 4, Appendix M, CIAP Monographs, Impacts of Climatic Change on the Biosphere; Part 1, Ultraviolet Radiation Effects. DOT-TST-75-55, Sept. 1975.

4-25. Biggs, R. H.; and Basiouny, F.: Plant Growth Responses to Elevated UV-B Irradiations under Growth Chamber, Greenhouse, and Solarium Conditions. Chapter 4, Appendix L, CIAP Monograph 5, Impacts of Climatic Change on the Biosphere; Part 1, Ultraviolet Radiation Effects. DOT-TST-75-55, Sept. 1975.

4-26. Halocarbons: Environmental Effects of Chlorofluoromethane Release. National Academy of Sciences, 1976.

4-27. Scotto, J.; Kopf, A. W.; and Urbach, F.: Non-Melanoma Skin Cancer Among Caucasians in Four Areas of the United States. Cancer, vol. 34, 1974, pp. 1333-1338.

4-27. Climatic Impact Committee: 1975 Environmental Impact of Stratospheric Flight: Biological and Climatic Effects of Aircraft Emissions in the Stratosphere. National Academy of Sciences (Washington, D.C.), 1975.

4-28. Pollack, J. B.; Toon, O. B.; et al.: Estimates of the Climatic Impact of Aerosols Produced by Space Shuttle SST's and Other High-Flying Aircraft, in Proceedings of the Space Shuttle Environmental Assessment Workshop on Stratospheric Effects. NASA TM X-58198, Jan. 1977.

4-29. Stolarski, R. S.; Cicerone, R. J.; and Nagy, F. F.: Impact of Space Shuttle Orbiter Re-Entry and Mesospheric NO_x. AIAA Journal, vol. 12, 1974, p. 395.

4-30. Whitten, R. C.; and Turco, R. P.: Perturbation of the Stratosphere and Mesosphere by Aerospace Vehicles. AIAA Journal, vol. 12, 1974, p. 1110.

4-31. Booker, Henry G.: A Local Reduction of F-Region Ionization Due to Missile Transit. J. Geophys. Res., vol. 66, 1961, p. 1079.

4-32. Barnes, Cecil, Jr.: Comments on Paper by Henry G. Booker, 'A Local Reduction of F-Region Ionization Due to Missile Transit.' J. Geophys. Res., vol. 66, 1961, p. 2589.

4-33. Jackson, J. E.; Whale, H. A.; and Bauer, S. J.: Local Ionospheric Disturbances Created by a Burning Rocket. J. Geophys. Res., vol. 67, 1962. p. 2059.

4-34. Mendillo, M.; Hawkins, G. S.; and Klobuchar, J. A.: A Large-Scale Hole in the Ionosphere Caused by the Launch of Skylab. Science, vol. 187, 1975, p. 343.

4-35. Mendillo, M.; Hawkins, G. S.; and Klobuchar, J. A.: A Sudden Vanishing of the Ionosphere Due to the Launch of Skylab. J. Geophys. Res., vol. 80, 1985, p. 2217.

4-36. Bernhardt, Paul A.: The Response of the Ionosphere to the Injection of Chemically Reactive Vapors. Technical Report No. 17, SU-SEL-76-009 (Stanford University), 1976.

4-37. Rooney, R. C., ed.: Water Quality Criteria 1972 - A Report of the Committee on Water Quality Criteria. Environmental Studies Board, National Academy of Sciences (Washington, D.C.), U.S. G80 5501-00520, 1974.

4-38. Environmental Statement for the National Aeronautics and Space Administration Office of Space Science Launch Vehicle and Propulsion Programs. NASA (Washington, D.C.), July 1973.

4-39. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1976. American Conference of Governmental and Industrial Hygienists.

4-40. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. U.S. Environmental Protection Agency, 55019-74-004, Mar. 1974.

4-41. Effects of Noise on Wildlife and Other Animals. U.S. Environmental Protection Agency, NTID 300.5, Dec. 31, 1971.

4-42. Seebass, A. R., ed.: Sonic Boom Research. NASA SP-147, 1967.

4-43. Plotkin, J. K.; and Cantril, J. M.: Prediction of Sonic Boom at a Focus. Wyle Laboratories, WR75-7, Oct. 1975.

4-44. Hicks, R. J.; Mendoza, J. P.; and Garcia, F., Jr.: A Wind Tunnel Flight Co-relation of Apollo 15 Sonic Boom. NASA TM X-62 (Ames Research Center), Jan. 1972.

4-45. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. EPA document 55019-74-004, Mar. 1974.

4-46. Holmes, C. R.; Brook, M.; Krehbiel, P.; and McCrary, R.: On the Power Spectrum and Mechanism of Thunder. J. Geophys. Res., vol. 76, 1971, p. 2106.

4-47. Report of the Sonic Boom Panel of the International Civil Aviation Organization (ICAO), Oct. 1970.

4-48. Thackray, R. L.; Touchstone, R. M.; and Bailey, J. P.: Behavioral, Autonomic, and Subjective Reactions to Low- and Moderate-Level Simulated Sonic Booms: A Report of Two Experiments and a General Evaluation of Sonic Boom Startle Effects. FAA-AM-74-9, Sept. 1974.

4-49. Martin, W. W.: Operation Cool Mink. USDA Press Release, May 12, 1970.

4-50. Intrieri, P. F.; and Malcolm, G. N.: Ballistic Range Investigation of Sonic-Boom Overpressures in Water. AIAA Journal, vol. II, no. 4, Apr. 1973, pp. 510-516.

4-51. Cook, J. C.; Goforth, T.; and Cook, R. K.: Seismic and Underwater Responses to Sonic Booms. J. Acoust. Soc. Am., 51:2(3), pp. 729-741, 1972.

4-52. Wilkins, M. E.: Sonic Boom Effect on Fish -- Observations. NASA TM X-62-163, May 1972.

4-53. Hazards of Chemical Rockets and Propellants Handbook: Vol. 1, General Safety Engineering Design Criteria. CPIA/194, May 1972.

4-54. The October 1973 NASA Mission Model Cost and Economic Analysis. Marshall Space Flight Center, NASA TM X-64802, Jan. 1974.

4-55. Letter from Taichi L. Nishihara (Acting Chief of the Engineering Division, Los Angeles District of the U.S. Army Corps of Engineers) to Mr. Michael Bureman (Advisory Council on Historic Preservation, Denver, Colorado), Oct. 6, 1976.

4-56. Letter from Herbert Rhodes (State Historic Preservation Officer for the Department of Parks and Recreation in the State of California) to Mr. Garth A. Fuquay (Chief of the Engineering Division, Los Angeles District of the U.S. Army Corps of Engineers), Sept. 20, 1976.

4-57. Letter from John D. McDermott (Director of the Office of Review and Compliance, Advisory Council on Historic Preservation) to Mr. Taichi L. Nishihara (Acting Chief, Engineering Division, U.S. Army Corps of Engineers, Los Angeles District), Oct. 14, 1976.

4-58. Letter from Ann Webster Smith (Director, Office of Compliance, Advisory Council on Historic Preservation) to Mr. Monte D. Wright (Director, NASA Historical Office, NASA, Washington, D.C.), Apr. 8, 1974.

5-1. Stolarski, R. S.; and Cicerone, R. J.: Stratospheric Chlorine. A Possible Sink for Ozone. Presented at the Internat. Assoc. Geomagnetism and Aeronomy Symp. (Kyoto, Japan), Sept. 10-12, 1973.

5-2. Molina, Mario J.; and Rowland, F. S.: Stratospheric Sink for Chlorofluoromethanes· Chlorine Atom Catalysed Destruction of Ozone. Nature, vol. 249, June 28, 1974, pp. 810-812.

5-3. Shuttle Growth Study (Booster and External Tank Options). SD-77-SR-0008, Rockwell International/Space Division, May 1977.

5-4. Vander Arend, P. C.; Stoy, S. T.; and Kranyecz, T. E.: Feasibility Study of Launch Vehicle Ground Cloud Neutralization. Cryogenic Consultants, Inc., NASA CR-145000. 1976.

5-5. Integrated Operations/Payloads/Fleet Analysis Final Report. Vol. II, Payloads. Aerospace Corp. rpt. no. ATR-72 (7231)-1, Aug. 1971.

5-6. Integrated Operations/Payloads/Fleet Analysis Final Report. Vol. V, Mission, Capture and Operations Analysis. Aerospace Corp. rpt. no. ATR-72 (7231)-1, Aug. 1971.

5-7. Economic Analysis of the Space Shuttle System. Vols. 1-3, Mathematica, Inc., Jan. 31, 1972.

5-8. The October 1973 Space Shuttle Traffic Model. NASA TM X-64751, Rev. 2, Jan. 1974.

5-9. The October 1973 Expendable Launch Vehicle Traffic Model. NASA TM X-64752, Rev. 2, Jan. 1974.

5-10. The October 1973 NASA Mission Model Analysis and Economic Assessment. NASA TM X-64798, Jan. 1974.

8-1. Jorgenson, J. G.; and Lauer, R. J.: Space Shuttle Propellants/Pressurants Plan -- Support Operations. Executive Summary, Bendix Launch Support Division, July 1975.

8-2. Rice, E. E.: Telephone Conversations Regarding Ammonium Perchlorate Costs and Energy Requirements. BMI-NLVP-TC-74-26, Battelle's Columbus Laboratories, Aug. 19, 1975.

8-3. Metal Statistics 1976. Fairchild Publications, Inc. (New York), 1976.

8-4. Chemical Statistics Handbook. Manufacturing Chemists Association (Washington, D.C.), 7th Edition, 1971.

8-5. Rice, E. E.: A Preliminary Evaluation of the Impact of Rising Energy Prices on the Shuttle Cost-Per-Flight. BMI-NLVP-IM-76-3, Battelle's Columbus Laboratories, Feb. 23, 1976.

8-6. Energy and the Environment - Electrical Power. Council on Environmental Quality, Aug. 1973.

8-7. Berry, R. S.; and Fels, M. F.: The Production and Consumption of Automobiles; An Energy Analysis of the Manufacture, Discard and Reuse of the Automobile and Its Component Materials. Report to the Illinois Institute of Environmental Quality (Dept. of Chemistry, University of Chicago), July 1972.

8-8. Berry, R. S.; and Makino, H.: Energy Thrift in Packaging and Marketing. Technology Review, MIT, Feb. 1974.

8-9. Shuldinger, H.: Recreation Roundup - Gas for Recreation. Popular Science, Apr. 1974.

8-10. 1972 Census of Manufacturers - Fuels and Electric Energy Consumed. MC72 (SR)-6, U.S. Dept. of Commerce, July 1973.

8-11. Hicks, G. V.: Energy Statistics: A Supplement to the Summary of National Transportation Statistics. U.S. Dept. of Transportation rpt. no. DOT-TCS-OST-73-34, Sept. 1973.

9-1. Mathematica, Inc.: Quantification of Benefits to the National Economy from Industrial Applications of NASA Technology. NASA CR-2673, Mar. 1976. Executive Summary, NASA CR-2674.

9-2. Evans, M.: Economic Impacts of NASA Research and Development Spending. Chase Econometric Assoc., Inc. Vol. I, Executive Summary, NASA CR-144351. Vol. II, Report, NASA CR-144352. Vol. III, Appendices, NASA CR-144353. Apr. 1976.

10-1. Space Shuttle Program Status Report. Sept. 30, 1977.

10-2. Letter from the Director of the Advisory Center on Toxicology, National Research Council.

10-3. Assessment of Alternatives for Canaveral National Seashore. U.S. Dept. of Interior, Nat. Park Services, Sept. 1977.

10-4. Solar Terrestrial Programs - A Five-Year Plan. Solar Terrestrial Programs Office, Office of Space Science, NASA, Jan. 1977.

10-5. Hudson, R. D.: Chlorofluoromethanes and the Stratosphere. NASA Pub. 1010, Aug. 1977.

C-1. Slade, D. H. ed.: Meteorology and Atomic Energy 1968. U.S. Atomic Energy Commission, 1968.

C-2. Stephens, J. Briscoe; and Stewart, Roger B.: Rocket Exhaust Effluent Modeling for Tropospheric Air Quality and Environmental Assessments. NASA TR R-473, June 1977.

C-3. Dumbauld, R. K.; and Bjorklund, J. R.: NASA/MSFC Multilayer Diffusion Models and Computer Programs - Version 5. H. E. Cramer Company, Inc., NASA CR-2631, Dec. 1975.

C-4. Gregory, G. L.; Wornom, D. E.; Bendura, R. J.; Wagner, H. S.: Hydrogen Chloride Measurements from Titan-III Launches at the Air Force Eastern Test Range, Florida, 1973 through 1975. NASA TM X-72832, NASA/Langley Research Center (Hampton, Virginia), Mar. 1976.

C-5. Gomberg, R. I.; and Stewart, R. B.: A Computer Simulation of the Afterburning Processes Occurring Within Solid Rocket Motor Plumes in the Troposphere. NASA TN-D-8303, Dec. 1976.

C-6. Goldford, A. I.; Adelfang, S. A.; Hickey, J. S.; Smith, S. R.; et al.: Environmental Effects from SRB Exhaust Effluents - Technique Development and Preliminary Assessment. NASA CR-2923, Nov. 1977.

C-7. Stephens, J. Briscoe; and Hamilton, P.A.: Diffusion Algorithms and Data Reduction Routine for Onsite Launch Predictions for the Transport of Titan III C Exhaust Effluents. NASA TN D-7862, Dec. 1974.

C-8. Stephens, J. Briscoe: Diffusion Algorithms and Data Reduction Routine for On-site Real-Time Launch Predictions for the Transport of Delta-Thor Exhaust Effluents. NASA TN D-8194, Mar. 1976.

C-9. Stephens, J. Briscoe, ed.: Atmospheric Diffusion Predictions for the Exhaust Effluents from the Launch of a Titan III C, December 13, 1973. NASA TM X-64925, Sept. 1974.

D-1. Chapman, Sydney: A Theory of Upper-Atmospheric Ozone. Mem. R. Meteorol. Soc. London, vol. 3 (1930), pp. 103-125. (Also in Phil. Mag., vol. 10 (1930), 345-357, 369-383.)

D-2. McElroy, M. B.; Wofsy, S. C.; Penner, J. E.; and McConnell, J. C.: Atmospheric Ozone: Possible Impact of Stratospheric Aviation. J. Atmos. Sci., vol. 31, 1974, p. 287.

D-3. Upper Atmospheric Research Office: The NASA Program on Upper Atmospheric Research. Office of Space Science, Washington, D.C., June 1976.

D-4. Potter, A. E.: Revised Estimates for Ozone Reduction by Shuttle Operations. JSC-13946, to be published.